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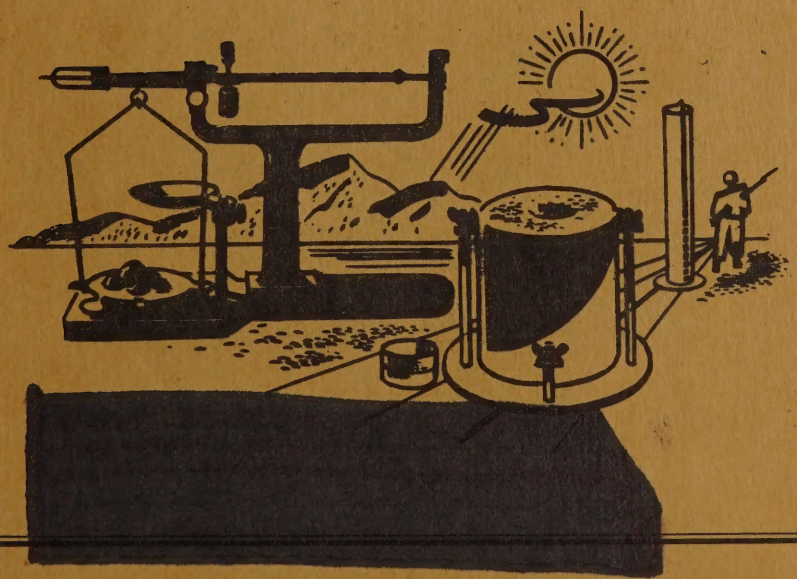
TB 5-253-1

WAR DEPARTMENT TECHNICAL BULLETIN

SOIL TESTING SET NO. 1 AND EXPEDIENT TESTS



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EPARTMENT, WASHINGTON 25, D. C., JUNE 1945

Washington 25, D. C., 21 June 1945.

TB 5–253–1, Soil Testing Set No. 1 and Expedient Tests, is published for the information and guidance of all concerned.

[AG 300.5 (21 June 1945)]

By order of the Secretary of War:

G. C. MARSHALL,
Chief of Staff

OFFICIAL:

J. A. ULIO
Major General
The Adjutant General

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Refer to FM 21–6 for explanation of distribution formula.

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TB 5-253-1
SOIL TESTING SET NO 1 AND EXPEDIENT TESTS

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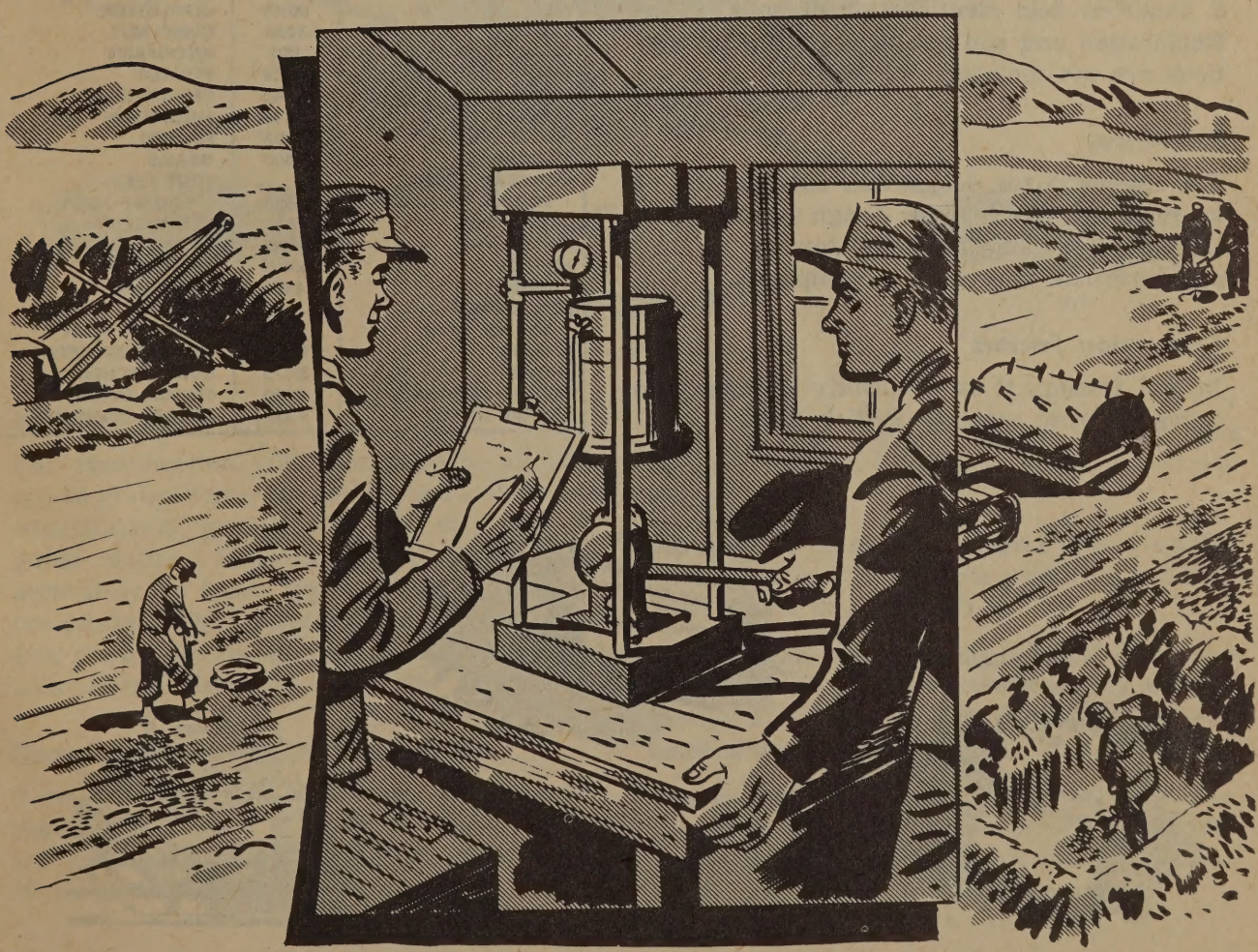
GENERAL



This Technical Bulletin has been prepared with the cooperation of the Graduate School of Engineering, Harvard University.

Purpose and Scope

This Technical Bulletin describes the laboratory soil testing set No 1 and its use for exploring and testing soils for airfields, roads, and shallow building foundations in theaters of operations.

It covers the following:

1. Description, care, and packaging of equipment furnished with the set.

2. Sampling and testing procedures adapted to set equipment.

3. Improvising test equipment to supplement set, or for use when set is not available.

4. Suggestions for field bearing and traffic tests.

5. Guide to field identification of soils.

Exploration and soil testing for deep foundations are not included.

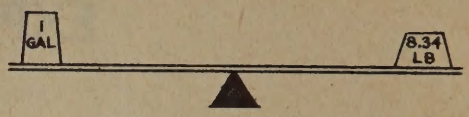
References

See TM 5-255 for design and construction of landing fields, FM 5-10 for design and construction of roads, and TM 5-252 for use of road and airdrome construction equipment.

Conversion Factors

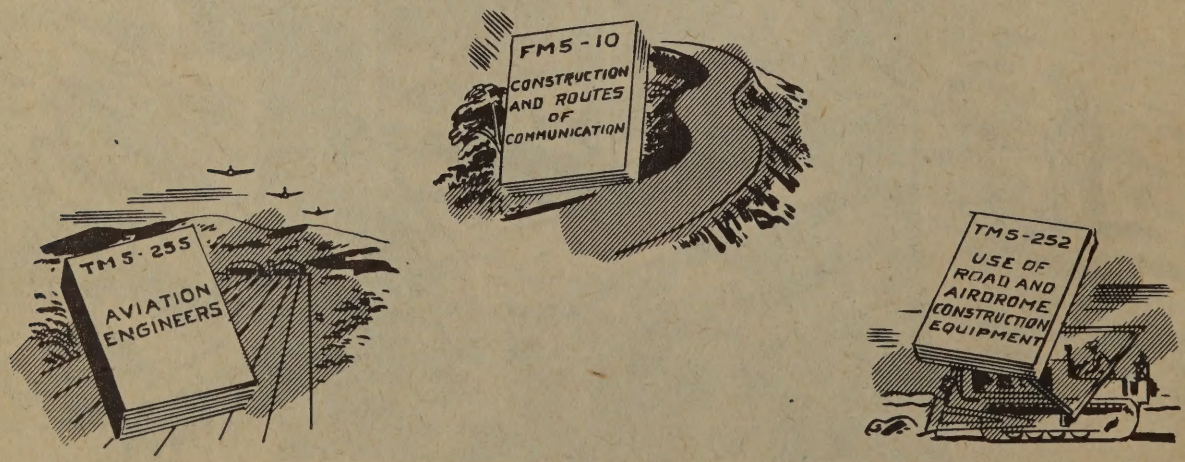
In soil testing, it is frequently necessary to convert metric units to British units.

1 CU FT WATER WEIGHS 62.4 LB



1 GAL WATER WEIGHS 8.34 LB.

MULTIPLY	BY	TO OBTAIN
CUBIC CENTIMETERS	.06102	CUBIC INCHES
CUBIC INCHES	16.39	CUBIC CENTIMETERS
CUBIC INCHES	.0005787	CUBIC FEET
CUBIC FEET	28,320	CUBIC CENTIMETERS
CUBIC FEET	1,728	CUBIC INCHES
CUBIC FEET	7.48	GALLONS
CENTIMETERS	10	MILLIMETERS
CENTIMETERS	.3937	INCHES
CENTIMETERS	.0328	FEET
FEET	30.48	CENTIMETERS
GALLONS	.1336	CUBIC FEET
GRAMS	.001	KILOGRAMS
GRAMS	.0022	POUNDS
INCHES	2.540	CENTIMETERS
INCHES	25.40	MILLIMETERS
KILOGRAMS	2.205	POUNDS
KILOGRAMS	1,000	GRAMS
KILOGRAMS PER SQUARE CENTIMETER	1.024	TONS PER SQUARE FOOT
MILLIMETERS	0.1	CENTIMETERS
MILLIMETERS	.03937	INCHES
POUNDS	453.6	GRAMS
POUNDS	.4536	KILOGRAMS
POUNDS PER SQUARE INCH	.072	TONS PER SQUARE FOOT
QUARTS	946.3	CUBIC CENTIMETERS
QUARTS	57.75	CUBIC INCHES
SQUARE CENTIMETERS	.1550	SQUARE INCHES
SQUARE INCHES	6.452	SQUARE CENTIMETERS



FIELD IDENTIFICATION OF SOILS

	PAGE
Classification and Description	3
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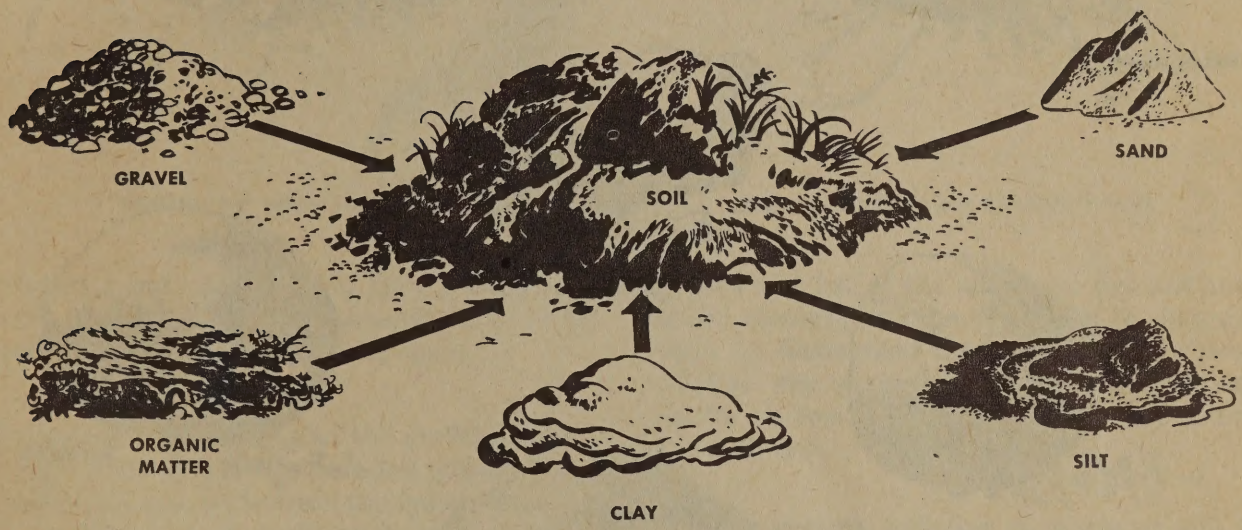
Correct soil identification is required for proper soil control. Lack of time or facilities often makes detailed soil classification tests impossible in military construction. Ability to identify soils in the field by simple visual inspection and examination by hand is important, since vital decisions must often be based on field identification. Even when time and facilities permit laboratory tests, a field examination is made when the sample is taken to describe the soil properly.

CLASSIFICATION AND DESCRIPTION



Principal Soil Types

For identification and classification, all soils can be grouped into five basic types and various combinations: gravel, sand, silt, clay, and organic matter. Soils in nature seldom exist separately as basic types, but are found as composites. Field identification and classification depend on recognition of basic soil types and characteristics of composite soils.

General Description of Basic Types

Gravel consists of bulky mineral grains larger than about ¼ inch in diameter. Large pieces are called stones; pieces larger than about 10 inches are called boulders.

Sand consists of mineral grains varying from about ¼ inch to 0.002 inch (0.05 mm) in diameter.

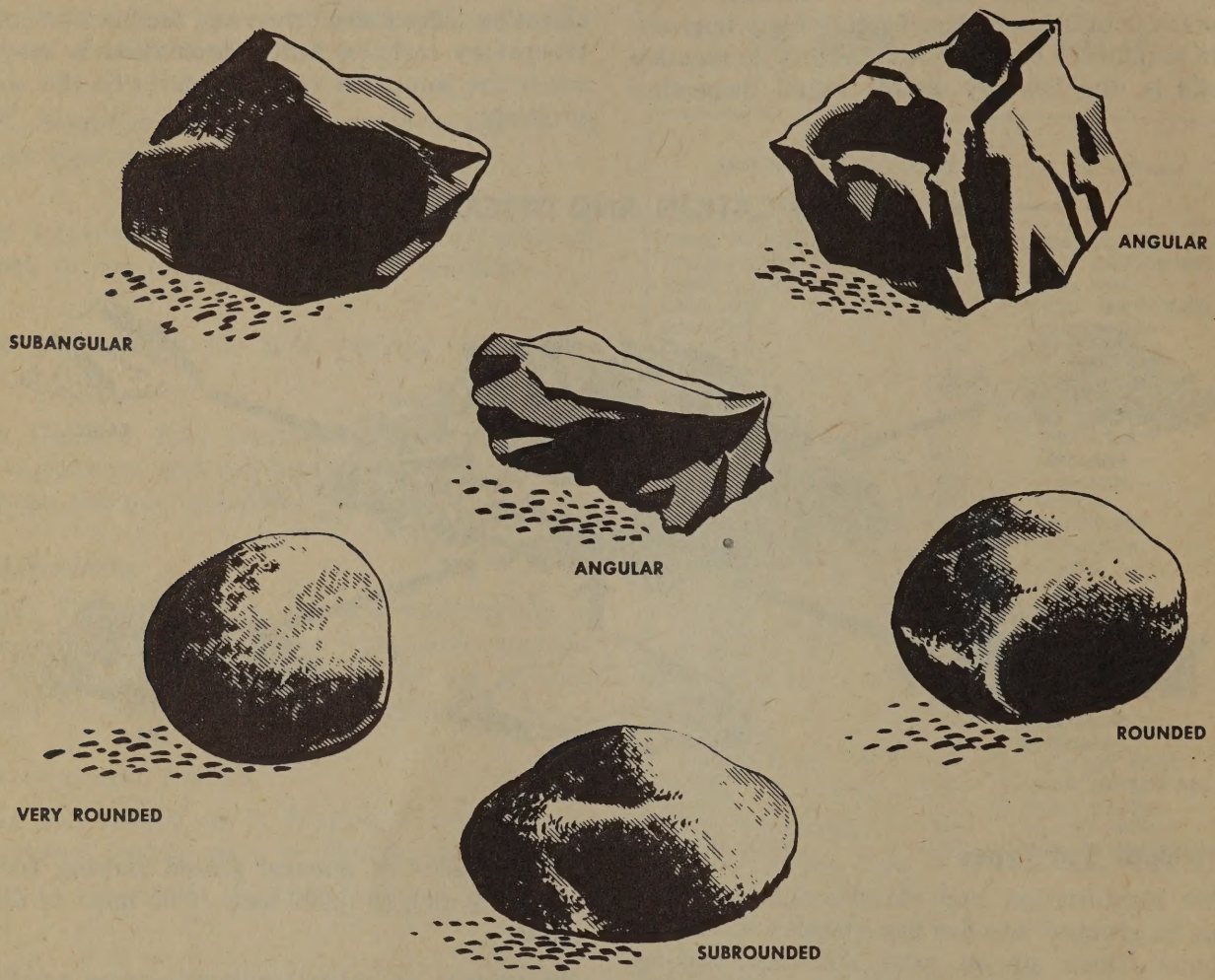
Silt consists of natural mineral grains smaller than 0.002 inch which lack plasticity and have little or no dry strength.

Clay contains colloidal scale-like particles which are the cause of plasticity. Plasticity and dry strength are affected by shape and mineral composition of the particles.

Organic matter consists either of partly decomposed vegetation as in peats, or of finely divided vegetable matter as in organic silts and organic clays.

FIELD IDENTIFICATION TESTS

The following simple tests can be performed without equipment and are helpful in identifying soils. Do not make a decision on the basis of a single test. Use all applicable tests, then identify the soil.



Visual Inspection

Grain shape. Observe and classify the sand and gravel particles as to degree of angularity or roundness.

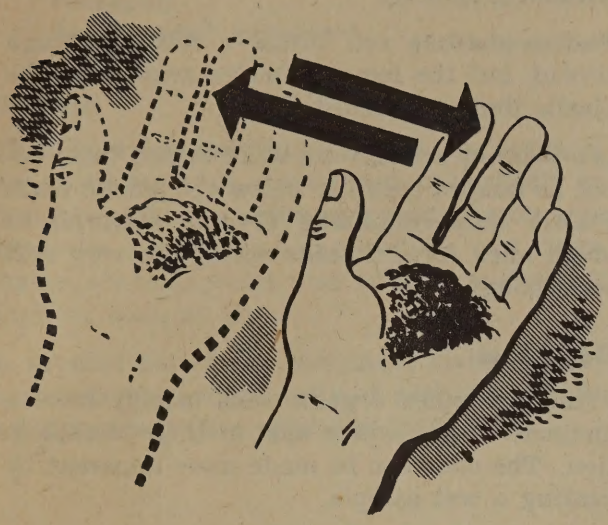
Grain size and gradation. Sand and gravel sizes are readily identified by visual inspection. Individual grains below the smallest sand size cannot be seen by the naked eye and must be identified by other tests.

For gradation of **coarse-grained soils,** spread a representative sample out on a flat surface and observe the distribution or uniformity of grain sizes.

For gradation of **fine-grained soils,** shake the sample in a jar of water and allow it to settle out. Approximate gradation is indicated by the separation of the particles in the jar from top to bottom. Silt remains in suspension for at least 1 minute; clay, 1 hour or more.

Shaking Test

The shaking test aids in the identity of fine-grained soils.



SHAKING THE MOIST SAMPLE

Prepare a pat of moist soil (try several pats with different moisture contents) and shake horizontally in the palm of the hand.

Observe if water comes to the surface of the sample, making it appear soft and glossy. Then squeeze the sample between the fingers, causing the moisture to disappear from the surface which changes from a shiny to a dull appearance. At the same time, the sample stiffens and finally crumbles under increasing finger pressure. Shake the broken pieces until they become livery and flow together again. Distinguish between slow, medium, and rapid reaction to the shaking test.

Rapid reaction indicates a lack of plasticity, such as is the case with a typical inorganic silt, a rock flour, or a very fine sand.

Slow reaction indicates a slightly plastic silt or silt clay.

No reaction indicates a clay or a peaty (organic) material.

Breaking Test

The breaking test may be used to determine the dry strength of a soil, which is a measure of its cohesiveness.

CRUMBLING DRY SAMPLE BETWEEN FINGERS

Allow a wet pat of the sample to dry and test its dry strength by crumbling with the fingers. Learn to distinguish between slight, medium, and high dry strength. Before drying sample, remove all coarse particles which would interfere with test.

Slight dry strength indicates an inorganic silt, a rock flour, or a silty sand. However, the sand feels gritty when sample is powdered.

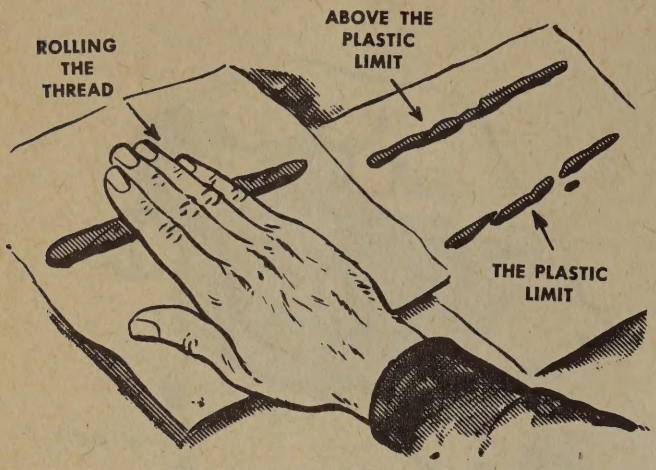
Medium dry strength indicates a low to medium plastic inorganic clay. Considerable finger pressure is required to powder the sample.

High dry strength indicates a highly plastic, inorganic clay. The dried sample can be broken but cannot be powdered by finger pressure.

NOTE: Cohesion or high dry strength may be furnished by some cementing material such as calcium carbonate or iron oxide. For example, nonplastic lime rock or coral may develop high dry strength.

Plasticity Tests

Plasticity is the physical property of a fine-grained soil which allows it to be kneaded into a putty-like consistency at the proper moisture content.



TESTING PLASTICITY OF SAMPLE

To test plasticity of a soil, prepare a moist pat and remove coarse particles. Start rolling it out with the palm of the hand on a flat surface into approximately ⅛-inch-diameter threads. Fold the threads into a lump, roll out again, and repeat process until moisture loss causes the thread to crumble when rolled. The moisture content at this stage is called the plastic limit. Note the toughness of the threads as the plastic limit is reached and test to see if the crumbled pieces can be lumped togther again.

Any soil that can be readily rolled into a thread without crumbling is plastic.

High-plasticity clay forms a tough thread which can be remolded into a lump below the plastic limit and deformed under high finger pressure without crumbling.

Medium-plasticity soil forms a medium tough thread, but the lump crumbles soon after the plastic limit is reached.

Low-plasticity soil forms a weak thread that cannot be lumped together below the plastic limit. Plastic soils containing organic material or much mica form threads which are very soft and spongy.

Odor Test

Freshly sampled organic soils usually have a distinctive odor which aids in their identification. The odor can be made more apparent by heating a wet sample.

Acid Test

Drop a little hydrochloric acid on a piece of soil. A fizzing reaction indicates calcium carbonate.

Shine Test

Rub a dry or slightly moist sample with the finger nail or a knife blade. A shiny surface indicates a highly plastic clay; a dull surface indicates a silt or clay of low plasticity.

EQUIPMENT

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Description and Use	7
Packaging	14
Supplemental Equipment	16

General

The laboratory soil testing set No 1 is designed for field use and is constructed as ruggedly as possible without sacrificing essential accuracy. However, neglect and carelessness can cause inaccurate tests which may be more misleading than no tests at all.

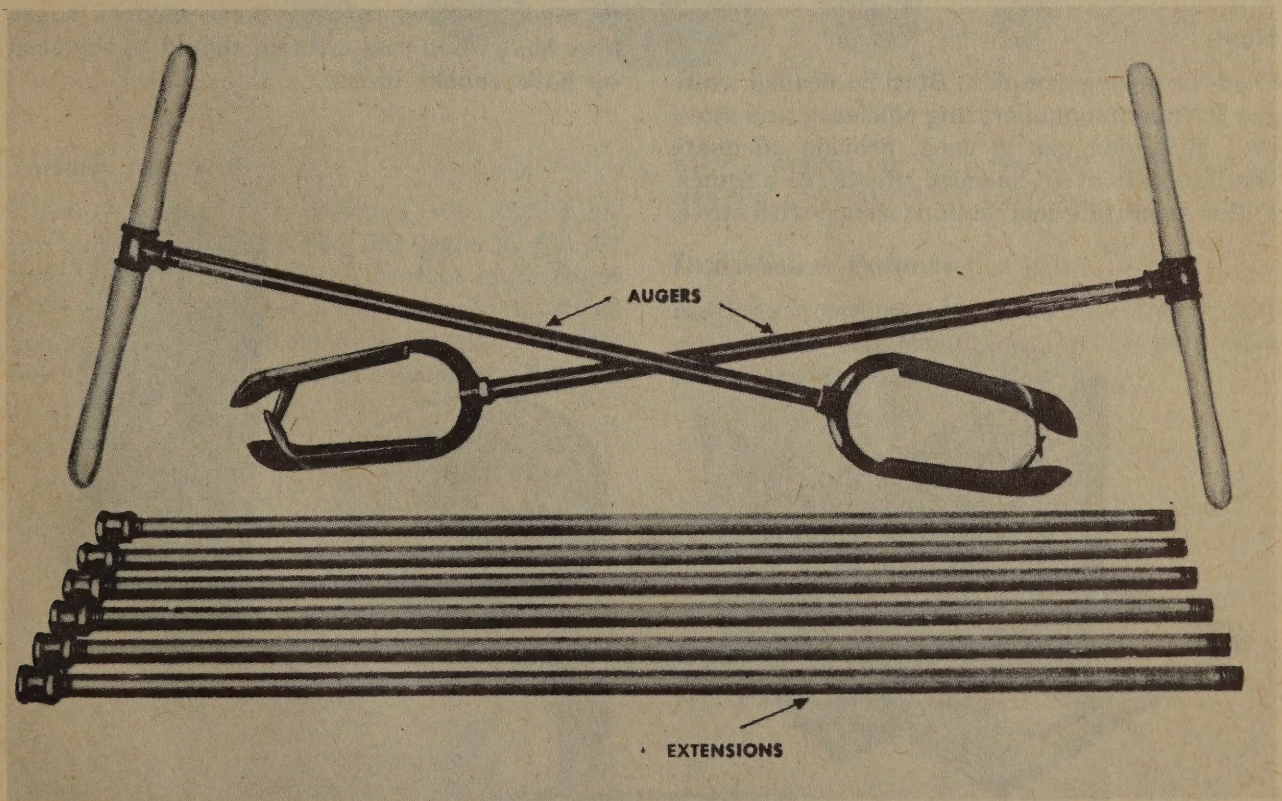
A detailed list of the equipment giving proper nomenclature and quantity of each item in the set appears in the appendix (page 89).

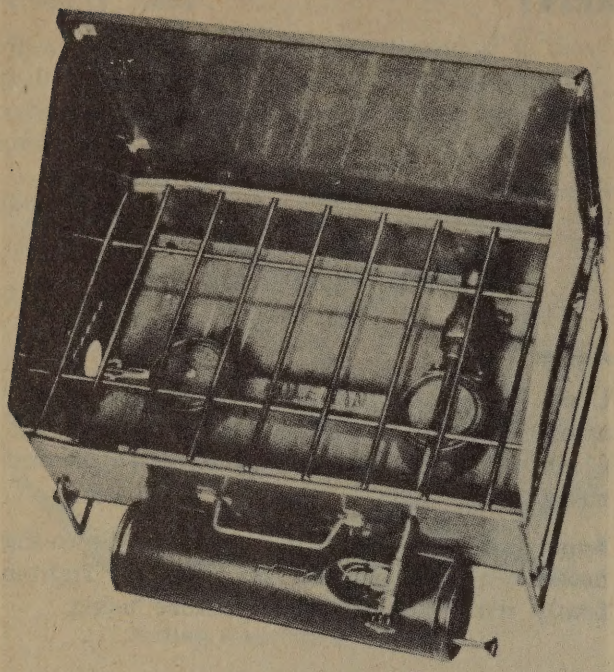
DESCRIPTION AND USE

Auger

Used for soil exploration and to obtain bag samples. Keep cutting edges sharp by filing. Clean and apply lard or engine oil to prevent rusting.

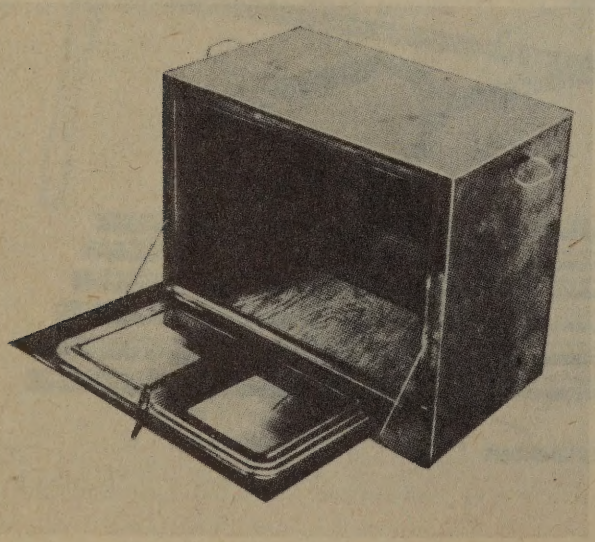
Auger Extension. Used to extend handle to dig holes to a depth greater than 4 feet. Tighten firmly with pipe wrenches before using.





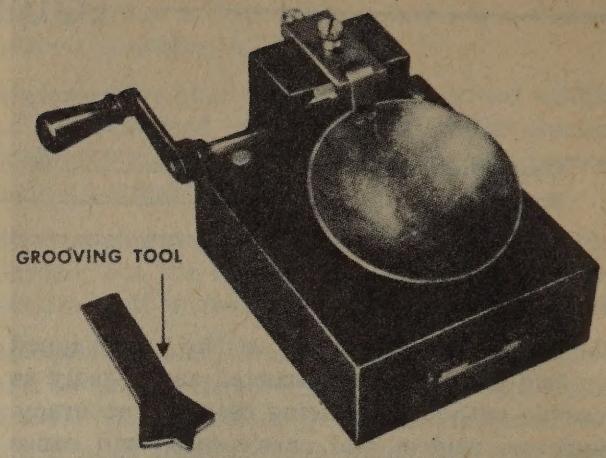
Stove

Used for drying samples. Burn nonleaded white gas for maximum operating efficiency and stove life. If leaded gas is used, provide adequate ventilation to avoid harmful effects from fumes. Follow operating instructions issued with stove.



Oven

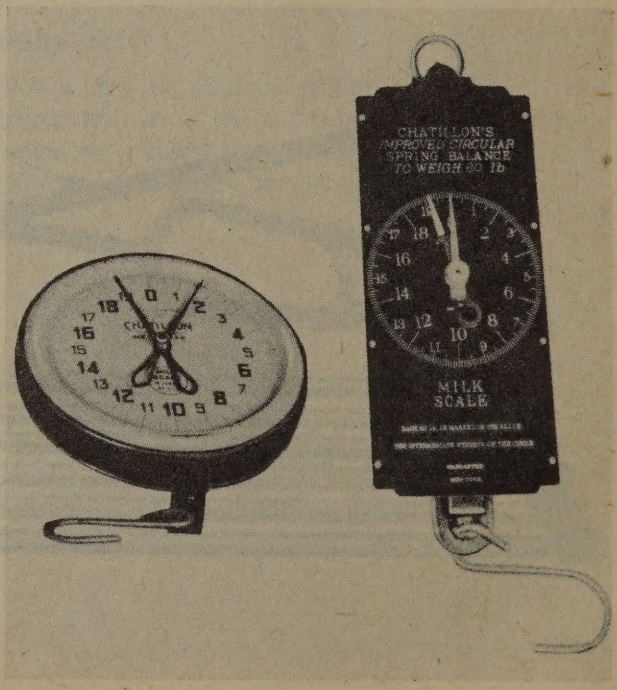
Used with stove for drying samples. Temperature is controlled by adjusting flame.



Liquid-limit Device

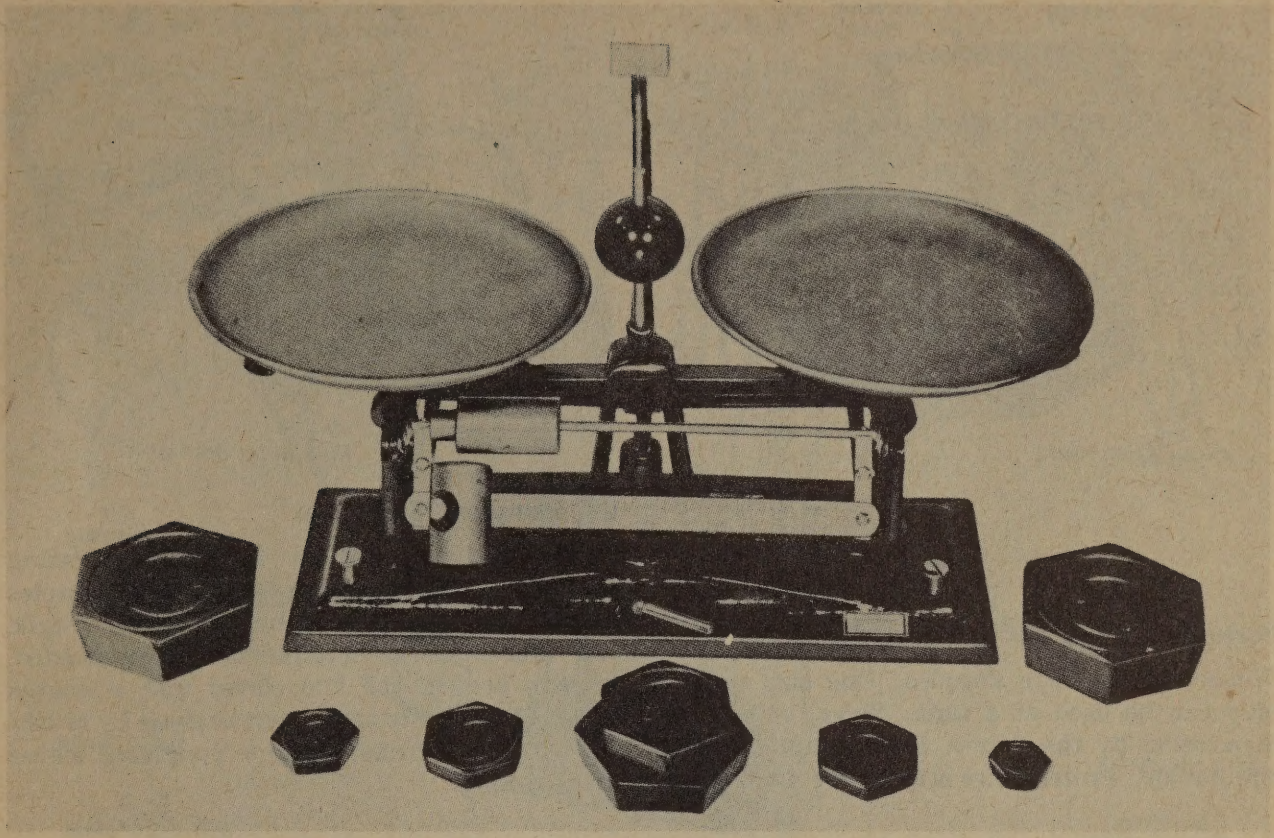
Used in making the liquid-limit test. Keep all parts clean and check adjustment frequently (page 51).

NOTE: For accurate results, the base should be made of hard rubber. Some models in use may have wood bases, which should be replaced by hard rubber bases.



Spring-balance Scales

Used for weighing samples in the field. (For use, see page 35.) Keep clean, free from rust, and check frequently for accuracy.

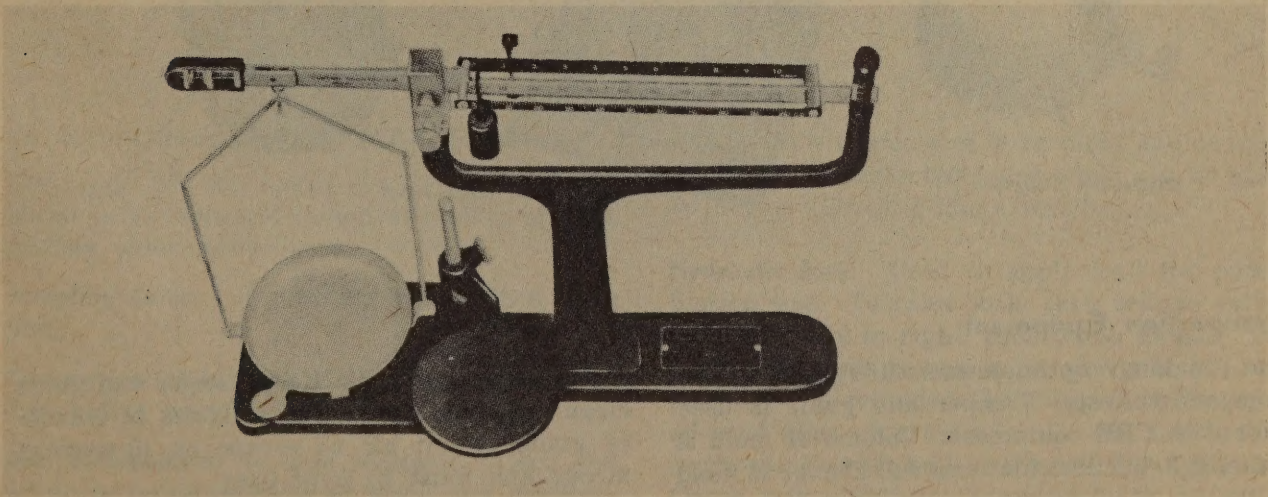


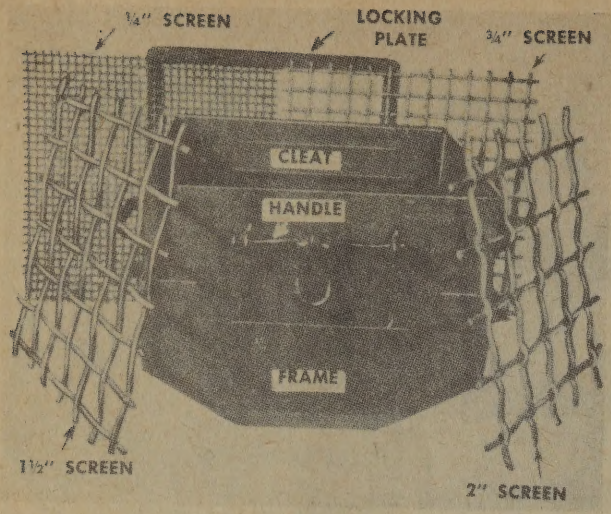
Torsion Balance

Used for weighings between 100 and 4,500 grams. Do not overload. See page 36 for detailed instructions on use. Protect knife edges from damage and keep away from dust. Check adjustment daily and clean moving parts weekly when in frequent use. Never leave the balance with a weight on the pans, and never use the weights for any other purpose.

Triple-beam Balance

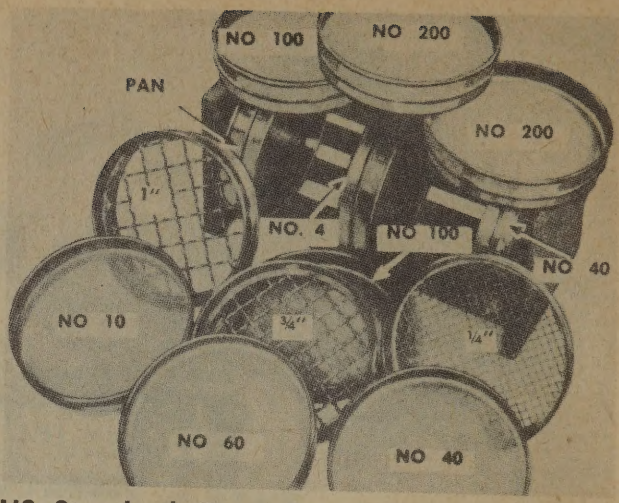
Used for weighings less than 200 grams. See page 37 for detailed instructions on use. Give same care as torsion balance.





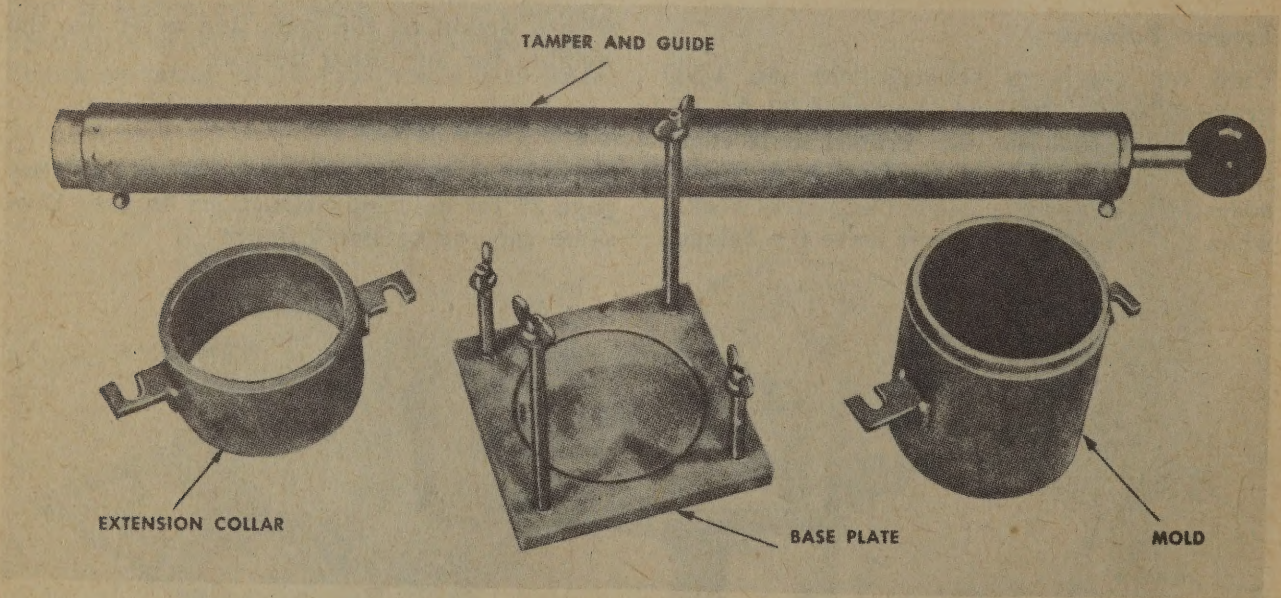
Portable Screen Set

For screening large samples. One size screen only can be used at a time. Screen is locked in position by the frame, cleat, locking plate, and handle. Protect wire screens from damage.



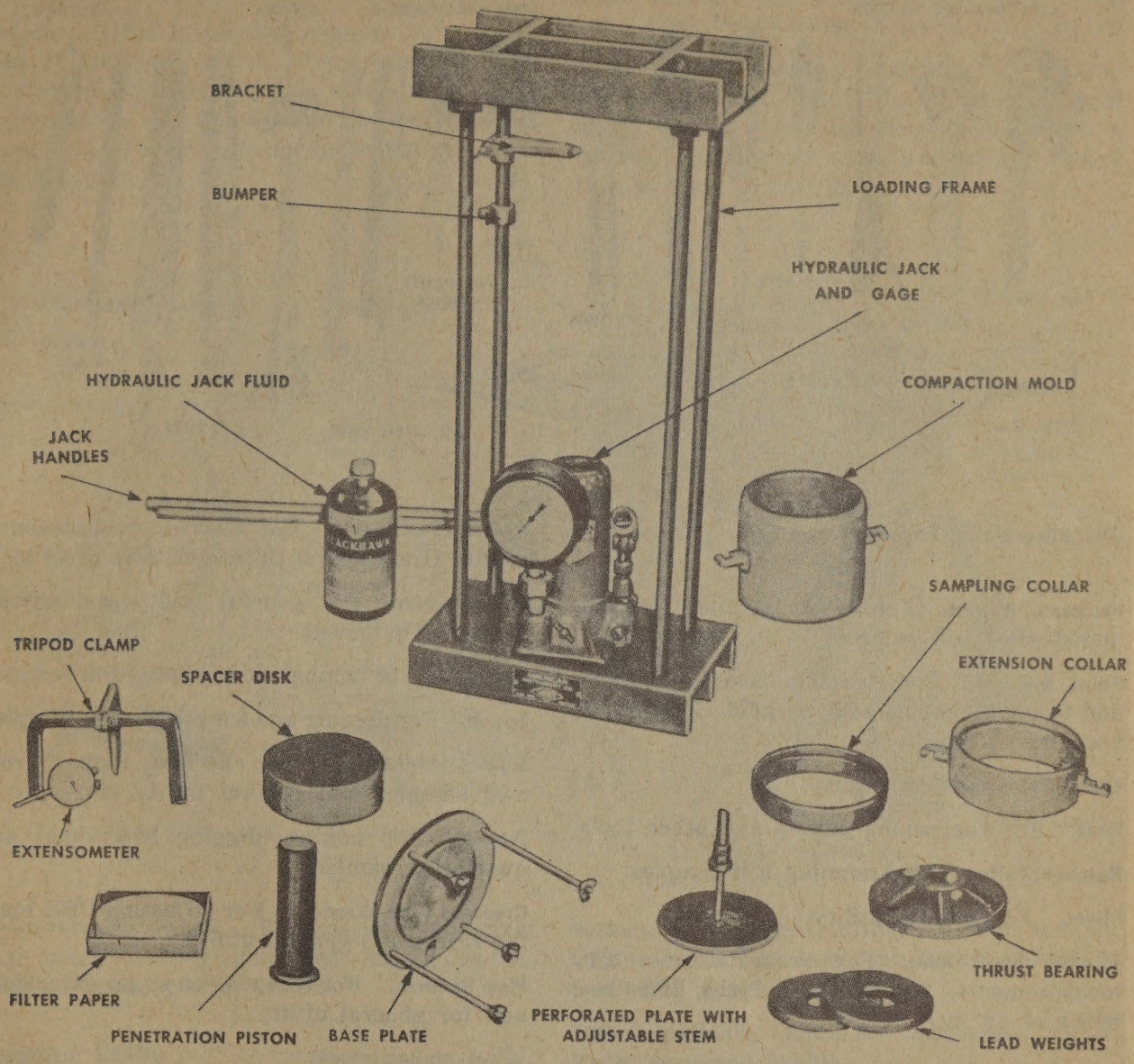
US Standard Sieve Set

Used for sieve analysis and for separating coarse material from fines in preparing samples for various tests. The fine sieves are fragile and must not be mistreated or overloaded. Always protect the fine sieves with a coarse sieve. Clean sieves after each analysis by brushing with paint brush. Repair punctured sieves by soldering.



Compaction Equipment

For making optimum-moisture-content and compaction tests. Tamper and guide is used also with CBR equipment. Volume of mold is exactly 1/30 cubic foot and will change if mold is dented or distorted. Keep tamper and guide clean so tamper falls freely. Holes in bottom of guide permit air to escape on downward stroke and must be kept open.



California Bearing Ratio (CBR) Equipment

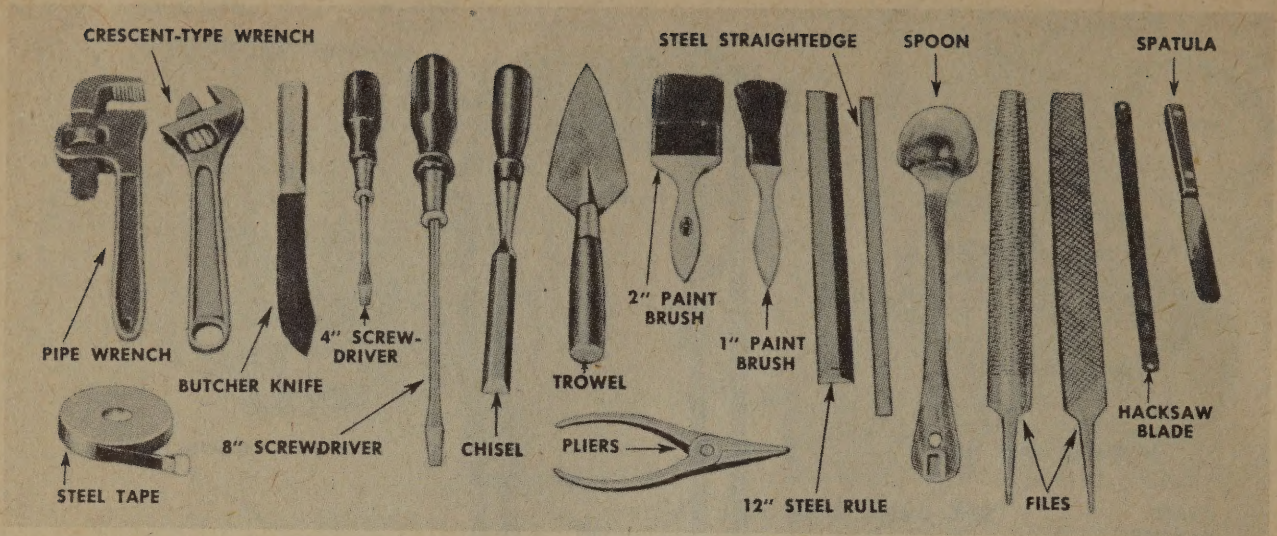
Used for CBR test (page 71). Keep unpainted metal parts clean and coated with oil to prevent rusting when not in use.

Sampling Collar. For taking undisturbed samples.

Compaction Mold with Collar and Base. For compacting samples before testing.

Dial Extensometer or Dial Indicator. Used for accurate measurements of swell and penetration. This is a precision instrument and should be kept in a protected place when not in use. Do not oil. Treat it like a watch.

Hydraulic Jack. Used to apply load for penetration test. To raise jack, turn release valve in base firmly to right, then pump handle. To lower jack, turn release valve slowly to left. A can of oil is provided for filling jack through oil-level filler plug on side. Do not use brake or shock-absorber fluid as this will damage jack. Check jack calibration occasionally by weights.



Miscellaneous Tools

Hacksaw Blades. For obtaining and trimming undisturbed soil samples.

Paint Brushes. For cleaning sieves and pans, and to coat samples with paraffin. Keep clean and dry.

Chisel. For general utility.

Files. For sharpening augers and other tools.

Butcher Knife. For trimming soil samples.

Pliers. For general utility.

12-inch Steel Rule. For accurate laboratory measurements. Graduated in 16ths, 32ds, and 64ths of an inch.

72-inch Steel Tape. For accurate field measurements. Graduated in 16ths and 32ds of an inch.

Screwdrivers. For general utility and adjustment of equipment.

Spatula. For mixing and trimming soil samples.

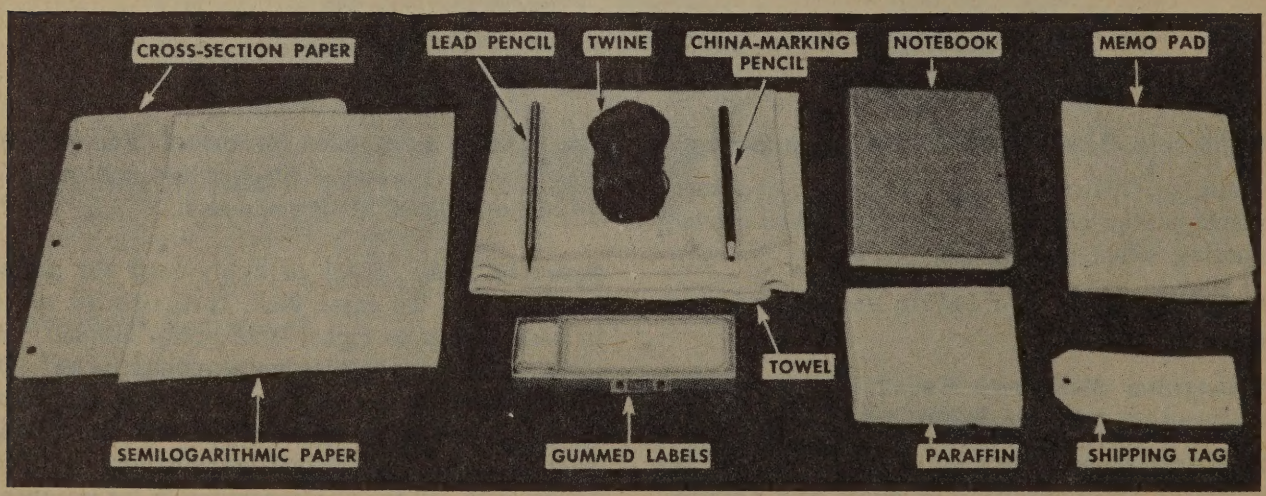
Spoon. For digging and for mixing soil samples.

Steel Straightedge. For checking ends of trimmed samples and general utility.

Trowel. For mixing, digging, trimming, and quartering samples.

Crescent-type Wrench. For adjusting CBR loading frame and general utility.

Pipe Wrench. For screwing on auger extensions and for general utility.

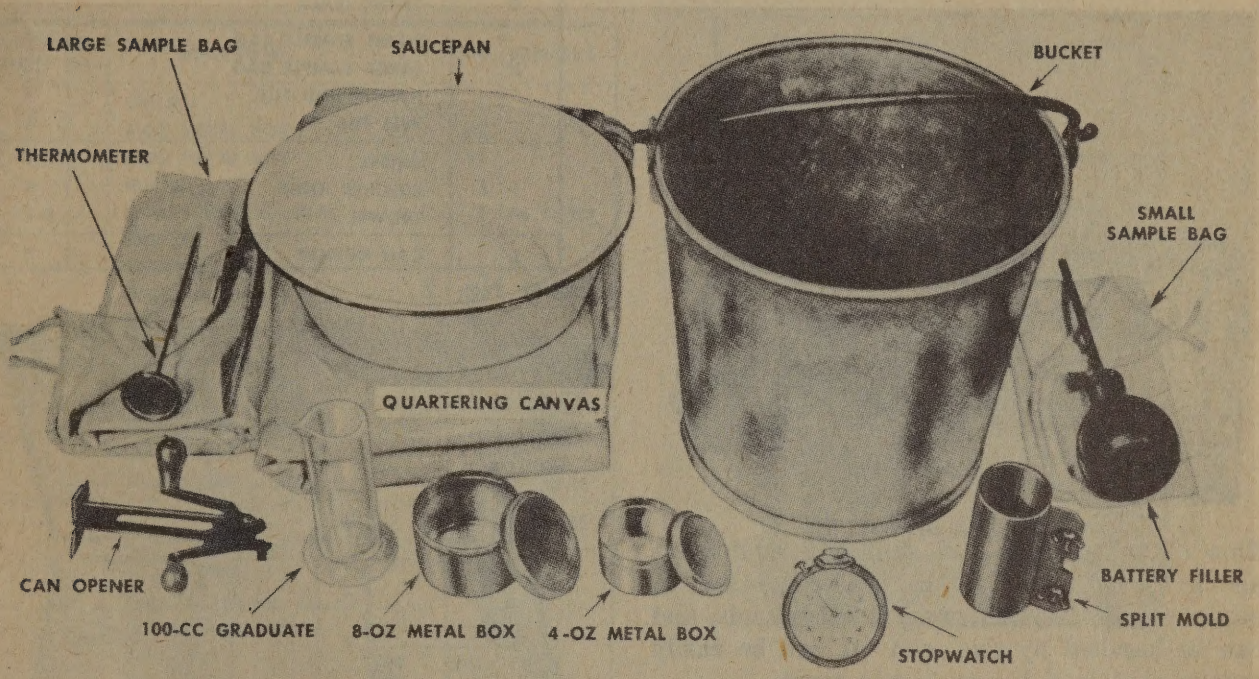


Miscellaneous Supplies

Paraffin. Used in coating samples to prevent loss of moisture. Care must be taken when heating over an open flame since it is highly inflammable. Do not continue to heat melted paraffin as it may become overheated and burn the brushes.

clean. When bags become soiled, turn inside out. Wash occasionally in warm soapy water.

Metal Boxes. Used as containers for making moisture-content tests. The small boxes hold about 4 ounces and the large boxes about 8 ounces. Number each box and lid and record tare weights to save time.



China-marking Pencils. For marking shipping tags and laboratory equipment. Marks are not affected by heat or moisture.

General Utility

Notebook
Gummed labels
Semilogarithmic paper
Shipping tags
Memorandum pads
Cross-section paper
Lead pencils
Towels, Twine

Miscellaneous Equipment

Sample Bags. For taking, transporting, and storing samples. The small sample bags are 10 inches by 18 inches and hold about 20 pounds of soil. The large sample bags are 17 inches by 32 inches and hold about 100 pounds of soil. After use with wet clays, turn inside out and scrape with straightedge or spatula. Then dry and beat against hard, smooth surface until

Buckets. For general utility and for soaking CBR samples. At least one bucket should be calibrated (page 18).

100-cc Graduate. Used for measuring liquids. Keep clean and usable.

Quartering Canvas. Keep clean and dry.

Battery Filler. Used for adding small quantities of water when mixing soils.

Split Molds. For compacting samples of remolded clay for compression or other tests.

Can Opener. For removing tops from cans to be used for sampling.

Saucepans. For drying and mixing samples and general utility.

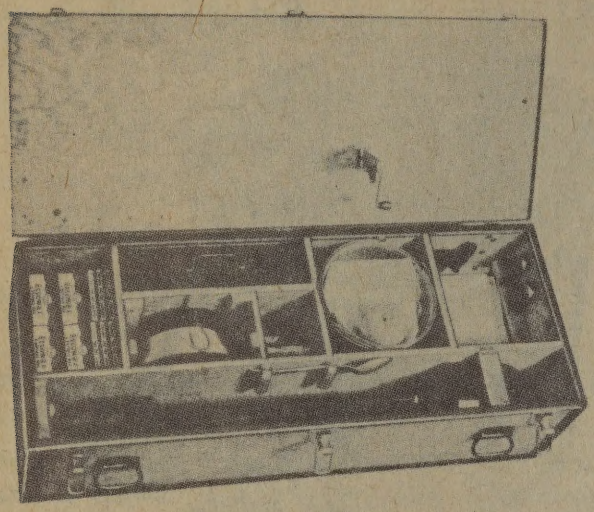
Thermometer. For determining temperature of drying oven.

Stopwatch. For determining rate of load penetration in CBR test. It should be cared for as any other watch.

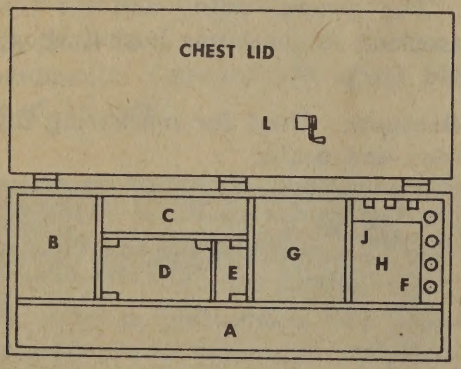
PACKAGING

Packaging details may vary with different manufacturers; weights, cubages, and dimensions may not be the same for all sets. Most sets are packaged in three chests as shown below, but newer sets are packaged in four chests. Equipment remains essentially the same.

Chest No 1



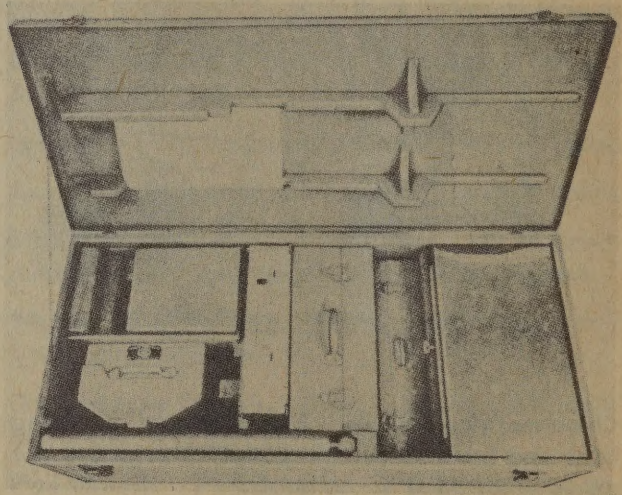
This chest contains soil sampling equipment and is moved about as the job progresses. It occupies 8.8 cubic feet, weighs 205 pounds, and can be handled by two men. It can be easily transported in a ¼- or ¾-ton truck.



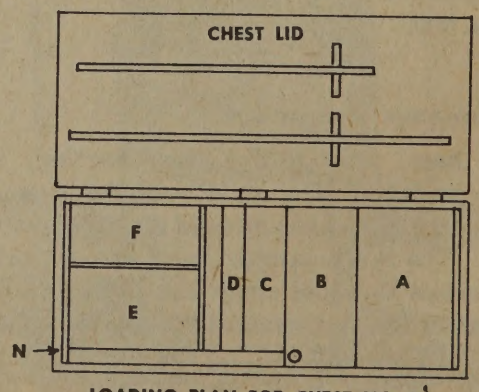
LOADING PLAN FOR CHEST NO 1

COMPARTMENT NO	EQUIPMENT	NO
A	AUGER	2
	AUGER HANDLE	2
	AUGER EXTENSION	6
	SPOON	1
B	PARAFFIN (1-LB PACKS)	25
C	GASOLINE STOVE	1
D	SAUCEPAN	6
	40-LB SPRING-BALANCE SCALE	1
	NOTEBOOK	1
	MEMO PAD	6
E	CHINA-MARKING PENCIL	3
	LEAD PENCIL	6
	STEEL TAPE	2
	SHIPPING TAG	100
F	PIPE WRENCH	4
G	BUCKET	2
	TWINE (BALL)	1
H	SMALL SAMPLE BAG	20
	LARGE SAMPLE BAG	5
	HALF-ROUND FILE	1
	MILL FILE	1
J	CHISEL	1
	BUTCHER KNIFE	1
	TROWEL	1
L	CAN OPENER	1

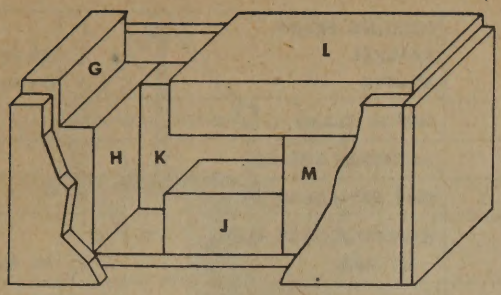
Chest No 2



This chest contains general laboratory soil testing equipment which is used wherever a field laboratory is set up. It occupies 14.0 cubic feet, weighs 330 pounds, and can be readily loaded into a light truck by four men.



LOADING PLAN FOR CHEST NO 2

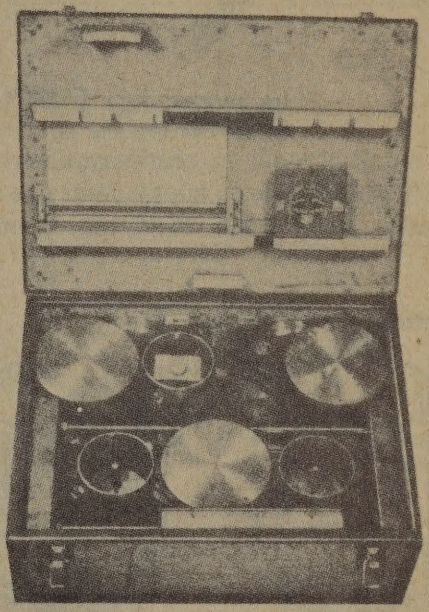


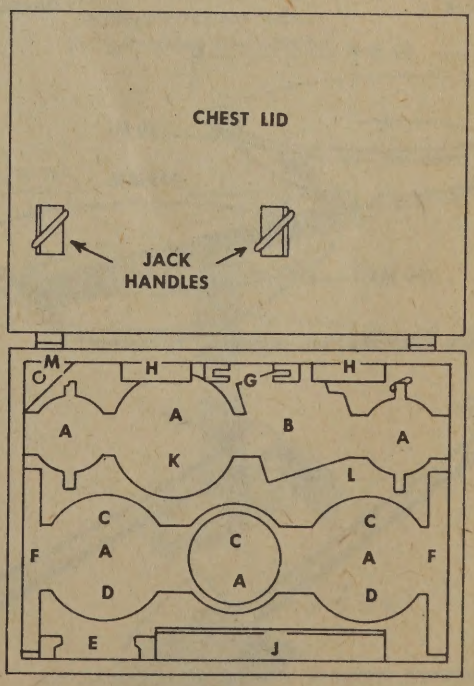
Chest No 3

This chest contains CBR equipment and is not used as frequently as the other two chests. It occupies 6.3 cubic feet, weighs 350 pounds, and has four handles.

NOTE: New sets may have the CBR equipment packaged in two chests, but items remain the same.

COMPARTMENT NO	EQUIPMENT	NO	REMARKS
A	OVEN	1	
	4-OZ METAL BOX	12	
	8-OZ METAL BOX	12	
	BUCKET	3	
	QUARTERING CANVAS	1	IN OVEN
	BATTERY FILLER	1	
	SAUCEPAN	18	
	CROSS-SECTION PAPER	100	
	SEMILOGARITHMIC PAPER	50	
	TOWEL	12	
B	TORSION BALANCE	1	IN CASE
C	TRIPLE-BEAM BALANCE	1	IN CASE
	STOPWATCH	1	IN BOX
	100-CC GRADUATE	2	IN CASE
D	STOVE	1	IN CASE
	HACKSAW BLADE	12	
	BUTCHER KNIFE	1	
	CHINA-MARKING PENCIL	3	
	LEAD PENCIL	6	
	PLIERS	1	
	12" STEEL RULE	1	
	4" SCREWDRIVER	1	
	8" SCREWDRIVER	1	IN BOX
	SPATULA	2	
	SPOON	1	
	STEEL STRAIGHTEDGE	1	
	TROWEL	1	
	CRESCENT-TYPE WRENCH	1	
E	PORTABLE SCREEN SET	1	
	SPLIT MOLD	3	
F	COMPACTION MOLD	1	IN TRAY
	US STANDARD SIEVE SET	1	IN RACK
G	THERMOMETER	1	IN TRAY
H	SCALE WEIGHTS (LARGE)	1	IN TRAY
J	SCALE WEIGHTS (SMALL)	1	IN TRAY
K	60-LB SPRING-BALANCE SCALE	1	IN TRAY
L	NOTEBOOK	1	
	1" PAINT BRUSH	2	
	2" PAINT BRUSH	2	IN TRAY
	GUMMED LABELS (BOX)	2	
	MEMO PAD	6	
M	LIQUID-LIMIT DEVICE	1	IN TRAY
N	COMPACTION TAMPER AND GUIDE	1	





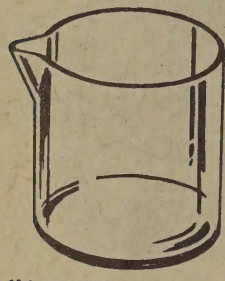
LOADING PLAN OF CHEST NO 3

COMPARTMENT NO	EQUIPMENT	NO	REMARKS
A	COMPACTION MOLD WITH COLLAR AND BASE	6	
B	HYDRAULIC JACK	1	
C	PERFORATED BASE PLATE	3	IN MOLD
D	5-LB LEAD WEIGHT	10	IN MOLD
E	THRUST BEARING	1	
F	LOADING FRAME BRACKET BUMPER	1 1 1	 ON FRAME ON FRAME
G	TRIPOD CLAMP	1	
H	SAMPLING COLLAR	2	
J	DIAL EXTENSOMETER	3	
K	HYDRAULIC-JACK FLUID, QT CAN	1	IN MOLD
L	FILTER PAPER (BOX)	1	LOOSE
M	PENETRATION PISTON	1	

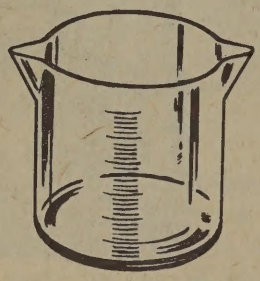
SUPPLEMENTAL EQUIPMENT

When using the set in semipermanent laboratories, it is desirable to supplement the set with equipment sometimes available from depot stock and with equipment improvised from local materials. Suggestions for supplemental equipment are illustrated below.

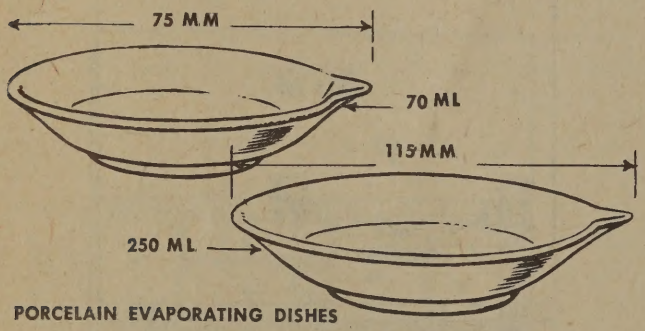
Equipment from Depot Stock



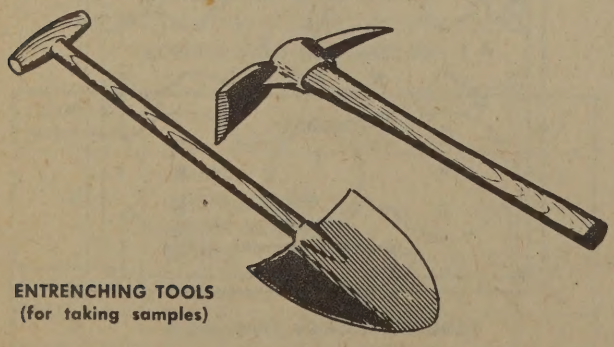
600 M L GLASS BEAKER



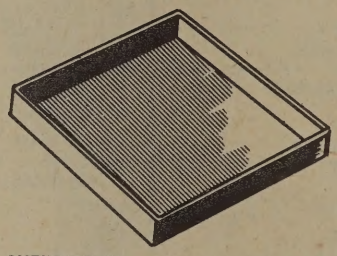
32-OZ GLASS GRADUATE



PORCELAIN EVAPORATING DISHES



ENTRENCHING TOOLS (for taking samples)

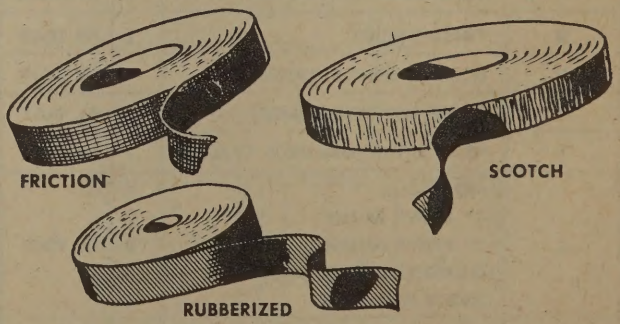


SHEET-METAL PAN

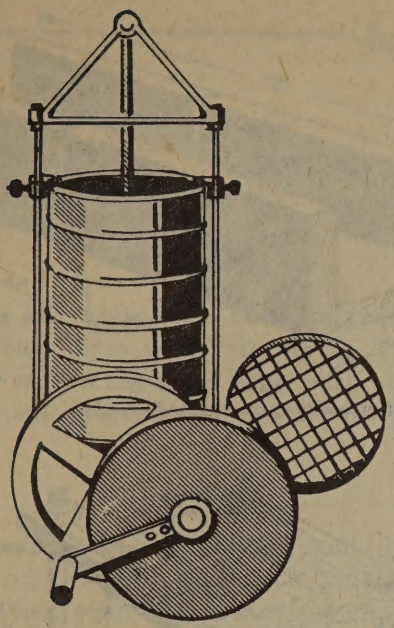
400 M L PORCELAIN MORTAR AND PESTLE

PYCNOMETER TOP (to fit 1-quart Mason jar)

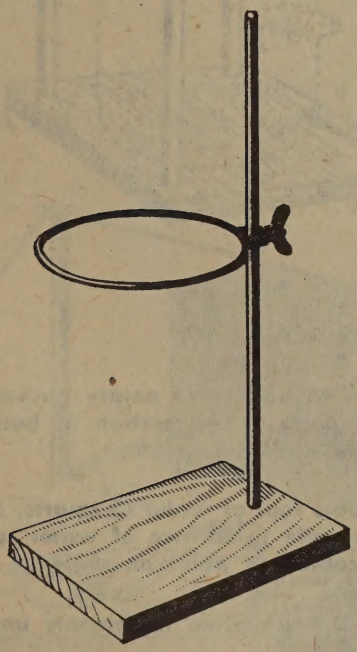
ENGINEER POCKET KNIFE (for trimming samples and general use)



SEALING TAPES (for sealing moisture-content and undisturbed samples)

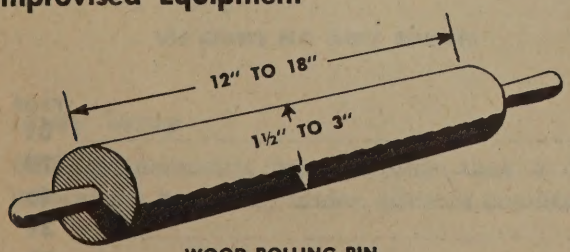


HAND-OPERATED SIEVE SHAKER

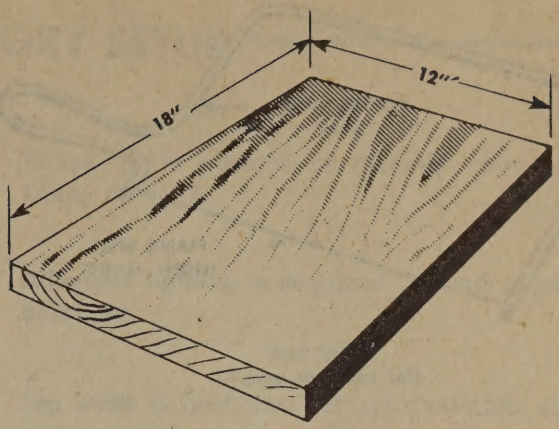


RING SUPPORT AND BASE

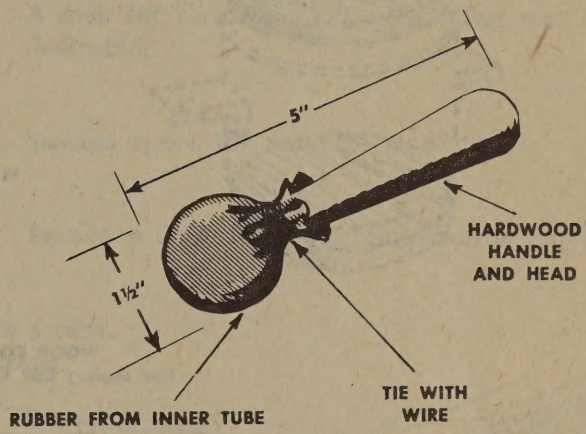
Improvised Equipment



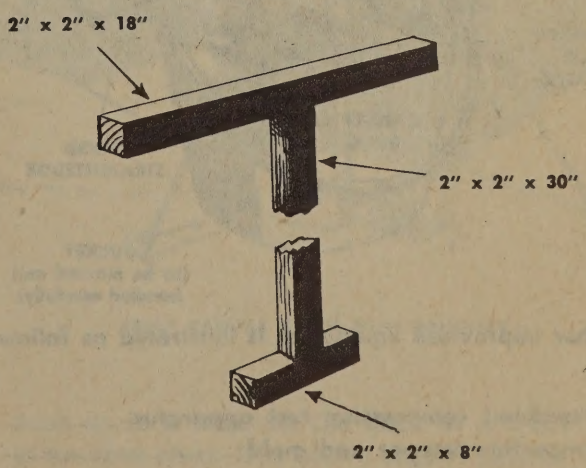
WOOD ROLLING PIN
(for breaking up lumps of coarse material)



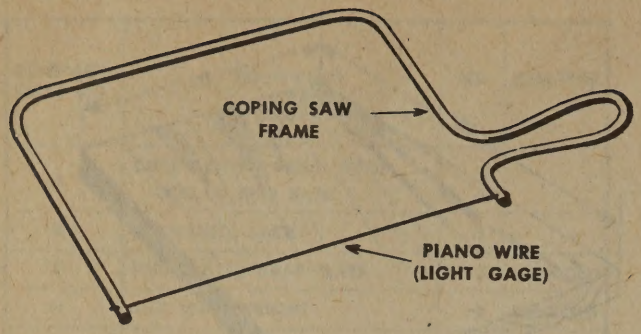
FLAT HARDWOOD BOARD
(for breaking up material)



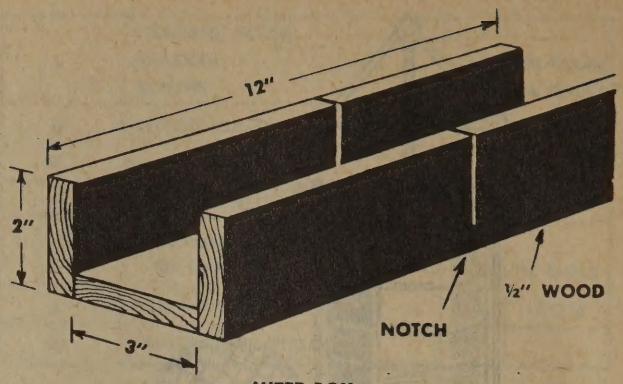
RUBBER-COVERED PESTLE
(for pulverizing fine material)



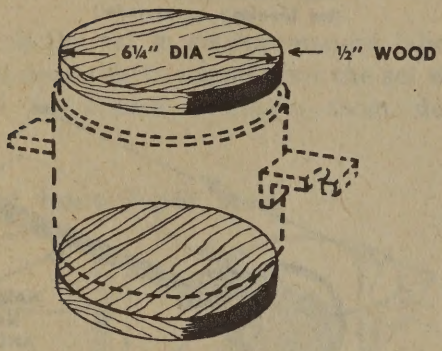
LOADING BAR (for pushing CBR mold into ground when taking undisturbed samples)

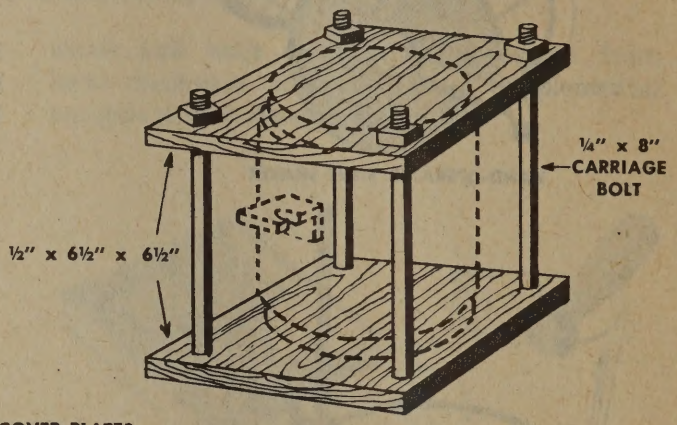


WIRE SAW
(for trimming samples)

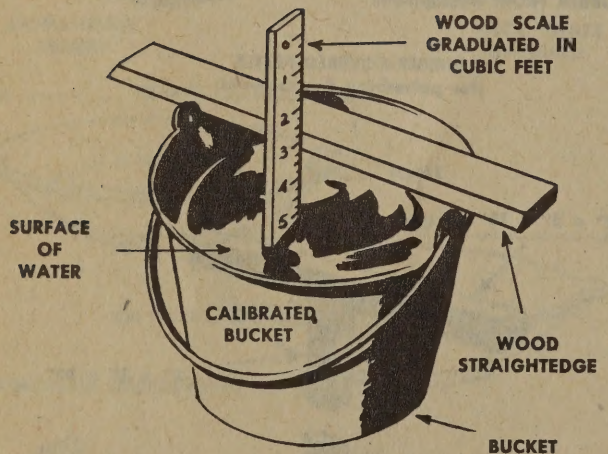


MITER BOX
(for trimming undisturbed samples)





WOOD COVER PLATES
(for sealing CBR undisturbed samples)



TO GRADUATE SCALE:

1. Insert scale to bottom of empty bucket and mark zero point at intersection of bottom of straightedge and scale
2. Add 0.1 cubic foot of water (3 quarts, or 2,839 cc), insert scale to surface of water, and mark 0.1-cubic-foot point on scale
3. Repeat at 0.1-cubic-foot increments until bucket is filled
4. Mark 10 equal divisions (0.01 cubic foot) between each set of points

Other improvised equipment is illustrated as follows:

	PAGE
Unconfined compression test apparatus	81
Compaction tamper and mold	70
Sedimentation chamber	46
Constant-volume can	39
Rubber membrane	59

LABORATORY SETUP

General Requirements

The following considerations are the most important in setting up any laboratory.

Torsion and triple-beam balances require a firm, level base free from vibration. They should not be set on the same table with other testing equipment and must be protected from air currents.

The gasoline stove and oven should be protected from air currents. The wind baffle is not effective when oven temperature must be carefully controlled.

Compaction equipment requires a firm foundation. A dirt or concrete floor is best; on wood floors, place equipment directly over a floor beam or joist.

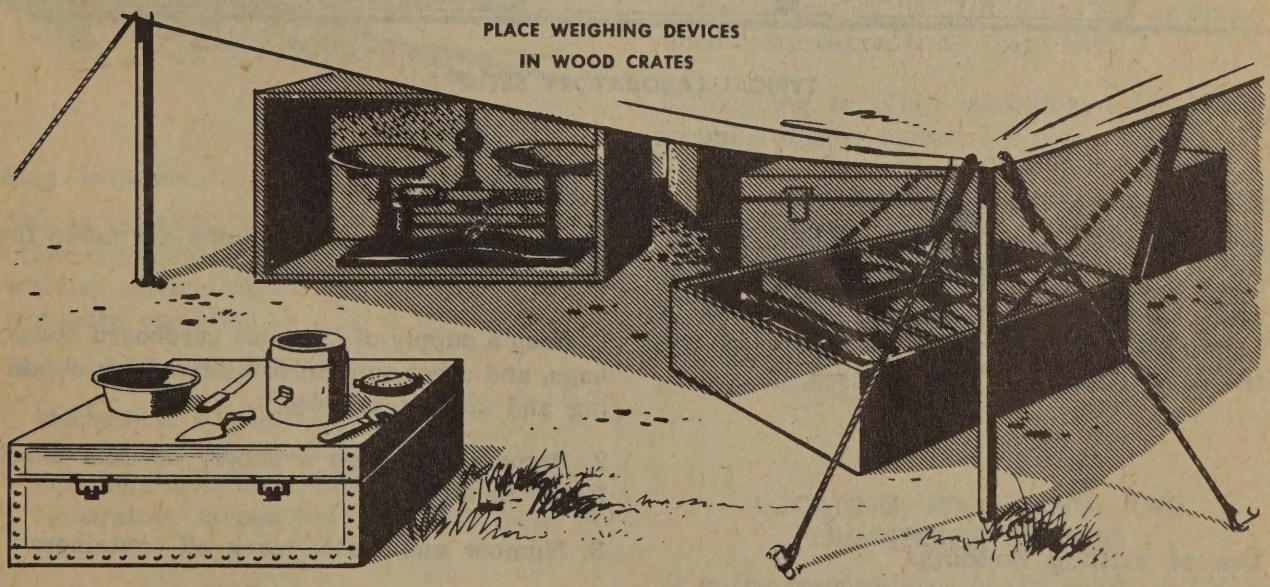
Adequate lighting is required to read gages and balances.

Tap water is desirable. If not available, enough water must be stored in laboratory for washing, mixing, and soaking samples.

A desk for recording and computing results is desirable.

Storage space for samples is required.

Protection from wind, rain, and sun is required.



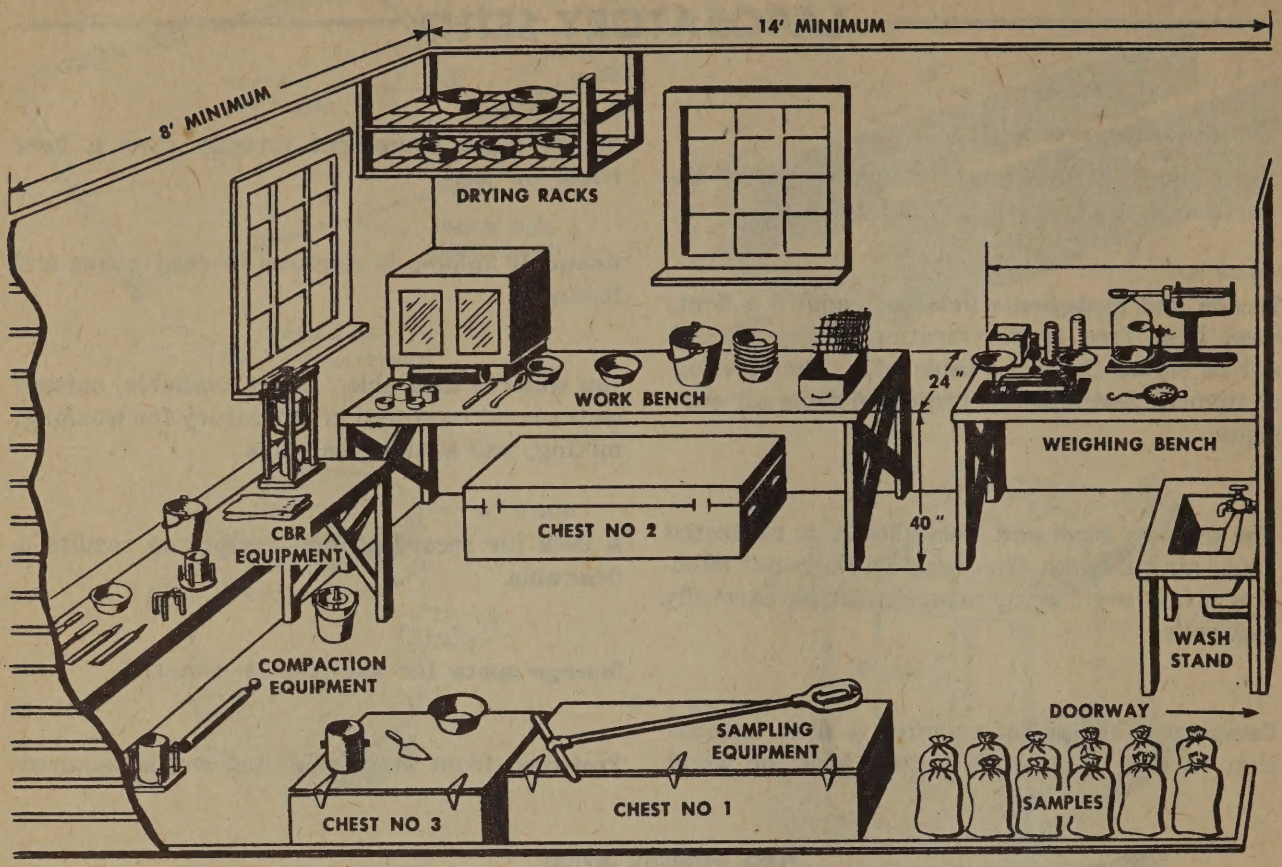
PLACE WEIGHING DEVICES IN WOOD CRATES

USE CHESTS FOR WORK BENCHES

ERECT CANVAS COVER OVER EQUIPMENT

Hasty Setup

Military necessity may require that a field laboratory be set up under adverse conditions, such as in a tent, on the back of a truck, or in an open shed. The above improvisations will protect the equipment.



TYPICAL LABORATORY SETUP

Semipermanent Laboratory

Efficient use of all the testing equipment requires a room about 8 feet wide and 14 feet long. By rearranging the equipment, buildings having different dimensions but approximately the same floor space can be used.

Use of Existing Buildings

The basement or first floor of an existing building is generally the most satisfactory for a laboratory because of the cool, damp air and solid floor. Compacting samples on an upper floor disturbs other occupants of the building unless the floors are solidly constructed.

Laboratory Hints

The following recommendations are made for semipermanent laboratories.

1. Keep a supply of tin cans, cardboard boxes, bags, and other containers on hand for obtaining and storing samples.

2. Prepare and keep a supply of data sheet forms in stock.

3. Number and match-mark all containers.

4. Weigh all containers accurately and record their weights either on a separate form or paint them on the containers.

5. Keep a supply of sealing materials, such as cellophane, waxed paper, and koroseal on hand for sealing samples.

SOIL EXPLORATION AND SAMPLING

	PAGE
General	21
Sampling Procedures	24

GENERAL

Types of soils to be sampled, number of samples to be taken, and where and how the samples will be taken is decided by the officer in charge of soil exploration.

TYPES OF SAMPLES

Bag Samples

Bag samples are taken by shovel, auger, or any other convenient hand tool and placed in bags without attempting to keep the soil in an undisturbed condition.

Bag samples are used for:

Mechanical Analysis (page 41)
Plasticity Test (page 50)
Optimum-moisture-content Test (page 65)
Laboratory compacted CBR Test (page 71)

Moisture-content Samples

To determine natural moisture content of soil, samples are taken in the field and placed in a container which is sealed to prevent loss of moisture by evaporation.

Undisturbed Samples

An undisturbed sample is soil that is cut, removed, and packed with the least possible disturbance. Undisturbed samples are used for:

1. Determining density (unit weight) in the laboratory (page 58).

2. Investigating strength of undisturbed soils in the laboratory by CBR (page 71) or unconfined compression tests (page 81).

3. Shipping to other laboratories for special examination or testing.

LOCATING, RECORDING, AND NUMBERING SAMPLES

It is the responsibility of the officer in charge of soil exploration to see that:

1. Each test pit, boring, or other exploratory excavation is properly surveyed, numbered, and recorded.

2. A log is kept of each test hole.

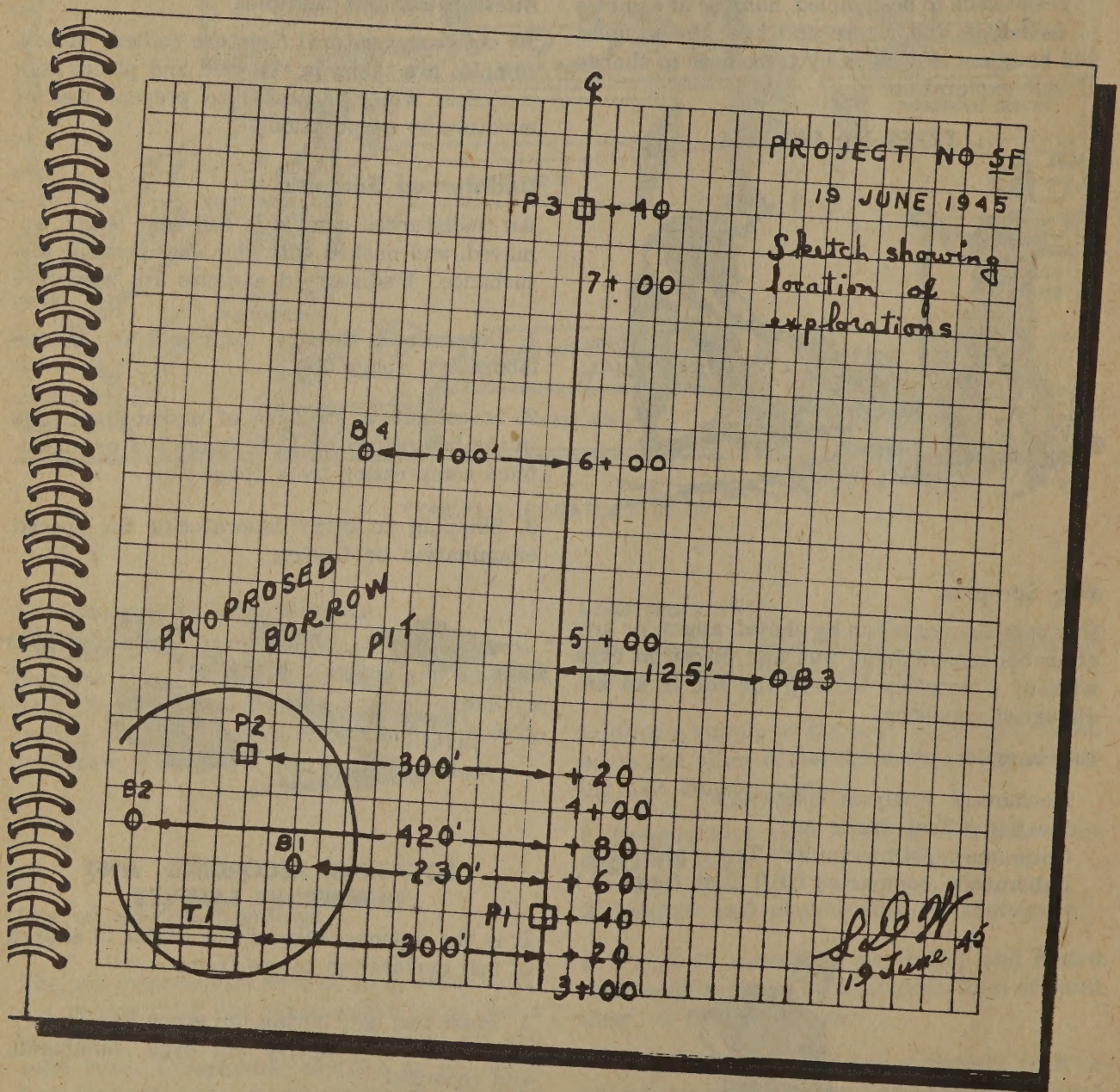
3. Each sample is properly numbered, tagged, and prepared for shipment.

Survey

Each test pit, boring, or other exploratory excavation is located by measuring or pacing right-angle offsets from the center line of the road or airstrip. Its location, type, and identification is plotted on a map or sketch in the notebook.

TYPE	ABBREVIATION	SYMBOL
PIT	P	□
BORING	B	○
TRENCH	T	▭

A uniform system of symbols should be used for plotting exploratory excavations. The symbols shown above are common.



Log

A detailed log is kept in the notebook of each exploratory excavation.

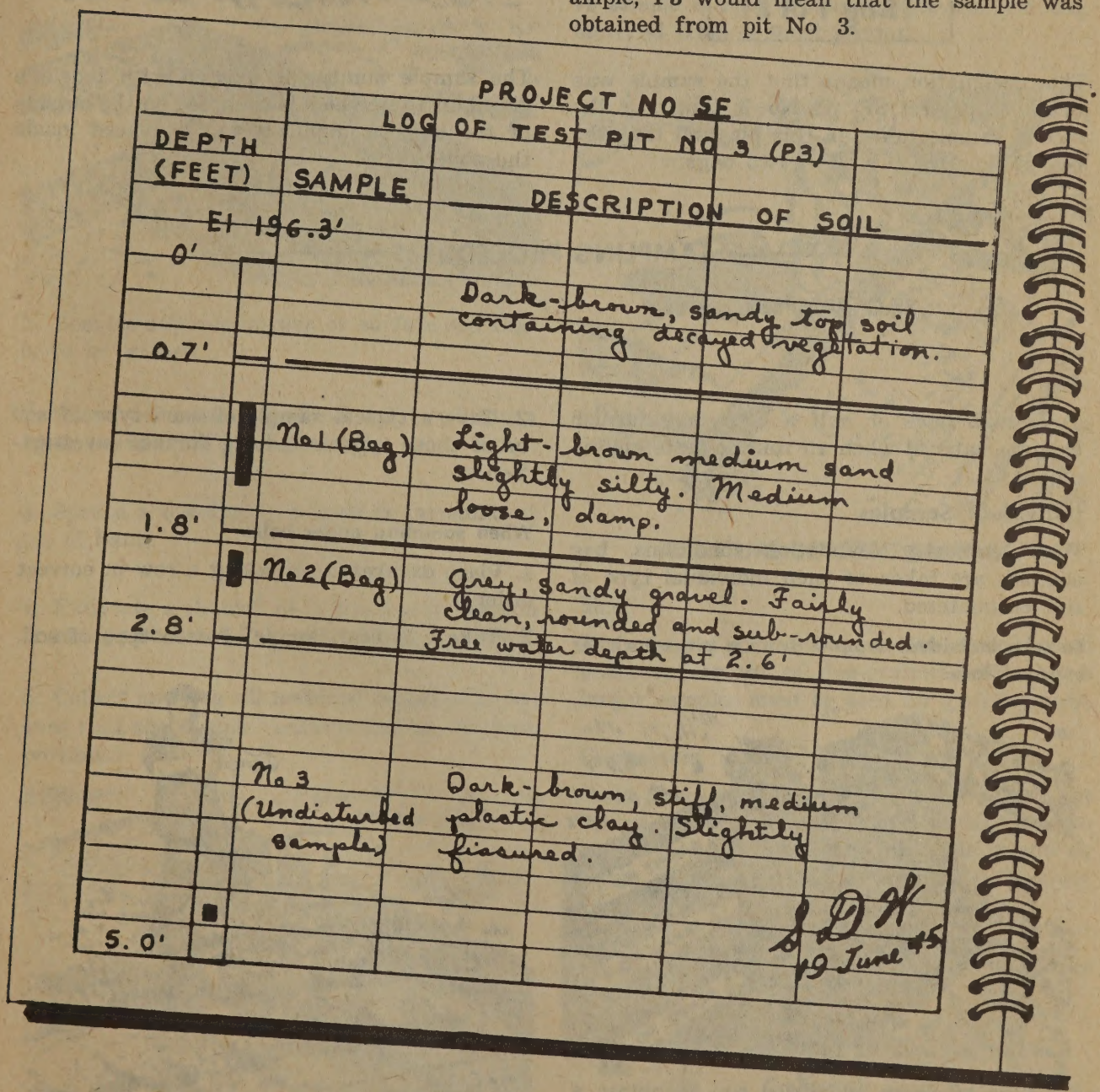
Logs must be complete and contain all information which might be of value in interpreting the test results and in plotting the soil profiles (see fig 29, TM 5-255).

Numbering Samples

Each sample is identified by the following information:

A project number consisting of a number, an abbreviation, or a symbol. For example, SF might be used for Smith Field.

An excavation number which corresponds to the number of the exploratory excavation. For example, P3 would mean that the sample was obtained from pit No 3.



A sample number which is the number of the sample in the order from which it was obtained from each location. If the sample consists of more than one bag, the total number of bags comprising the sample must also be recorded.

An example of a complete designation number is:

SF - P3 - 2
(Bag 1 of 2)

This designation means that the sample was taken on project SF, pit No 3, that it is the second sample taken in this pit, and that the bag is No 1 of a total of two bags.

The sample number is printed with indelible pencil on a tag which is then tied on the outside of the bag. A duplicate tag is placed inside the container.

SAMPLING PROCEDURES

BAG SAMPLES

Size

Two small bags or half a large bag furnish enough material when all routine tests are required.

Individual Samples

When exploring foundation conditions, bag samples are taken of each individual type of soil encountered.

To take individual samples from a pit, trench, or exposed face:

1. Shave off loose and dried soil to obtain a fresh surface and to expose clearly any variations in the soil.

2. Take a typical sample of each type of soil or of those types requiring further investigation.

When sampling auger holes:

1. Place excavated soil along a row in correct order.

2. Take a typical sample of each type of soil.

Composite Samples

The purpose of a composite sample is to obtain a representative mixture of all soil within a profile to be investigated or of the material contained in a stock pile or windrow. A test sample is obtained from composite samples by quartering (page 33) in the laboratory.

To take composite samples from test pits, trenches, or power-shovel cuts:

1. Remove any overburden or surface soil that is to be wasted.

2. Shave off loose and dried soil to obtain a fresh surface for taking sample.

3. Spread a quartering canvas or tarpaulin at toe of bank.

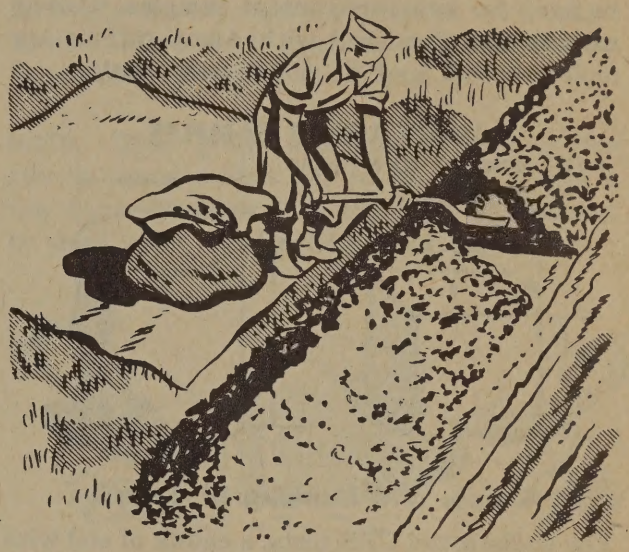
4. Excavate a channel of uniform cross section from top to bottom. Deposit material on canvas.

5. Collect and bag all material removed to assure that the sample contains the correct proportions.

For composite samples from auger holes, collect all material excavated from the hole after first removing overburden.

For composite samples from stock piles or large windrows, take particular care to obtain a representative sample. In dumping material on large piles, the coarse material tends to roll to the bottom, leaving the finer material in the upper portion.

To sample a small windrow, excavate and bag material from a short section.



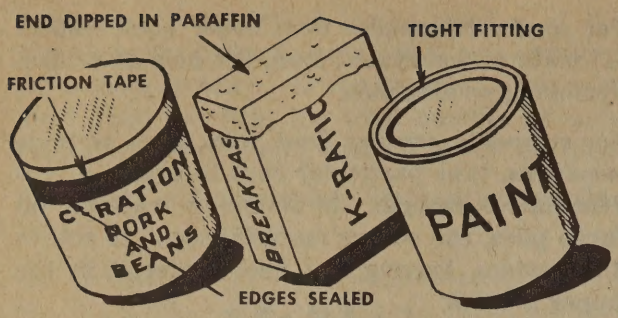
MOISTURE-CONTENT SAMPLES

Size

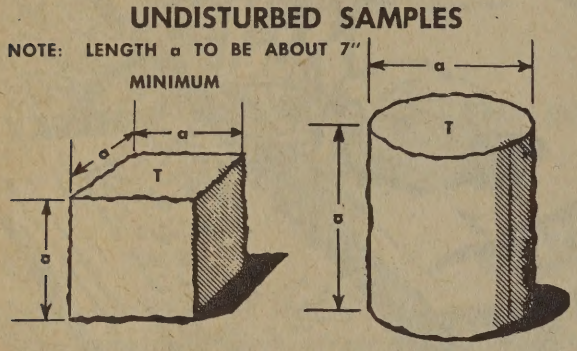
Ten grams of soil is enough to determine natural moisture content of fine-grained soils. Much larger samples must be used for gravelly soils.

Containers

Metal boxes furnished with the set have tight fitting covers and do not require sealing if the test is made within 1 day after the sample is taken. Three suggested methods of sealing are shown below:



Any other clean containers having covers which can be sealed with friction tape or paraffin can be used for moisture-content samples. Coffee-extract tins furnished with Army rations are moistureproof and do not require sealing.



Size, Shape, and Marking of Samples

For undisturbed CBR tests, a chunk of soil with a minimum dimension of 7 inches is satisfactory. For other tests, much smaller samples may be used. Top and bottom surfaces should be plainly marked with the letters T and B.

Tools and Supplies

Choose cutting tools which are best for each type of soil. The following tools and supplies will be helpful in taking undisturbed samples.

Set Equipment	Supplemental Equipment	Improvised Equipment
Spoon	Entrenching Tools	Wire Saw (Page 18)
Cord	Pocket Knife	Wood Discs (Page 18)
Paint Brush	Cheese Cloth	Loading Bar (Page 17)
Stove	Shovel or Spade	
Paraffin	Friction Tape	
Screwdriver	Paper	
Trowel	Suitable Containers	
Butcher Knife		
CBR Compaction Mold		
Straightedge		
Hacksaw Blades		

Chunk Samples

The simplest type of undisturbed sample is obtained by cutting out a chunk of soil of the desired size and covering it to prevent loss of moisture and breakage. This method can be used only with soils that will not deform, break, or crumble when being removed.

To obtain a chunk sample from a subgrade or other level surface such as the bottom of a test pit:

1. Smooth ground surface and mark outline of chunk.
2. Excavate trench around chunk.

3. Deepen excavation and trim sides of chunk with butcher knife.

4. Cut off chunk with butcher knife, trowel, or hacksaw blade and carefully remove from hole.

To obtain a chunk sample from the vertical face of a test pit or shovel cut:

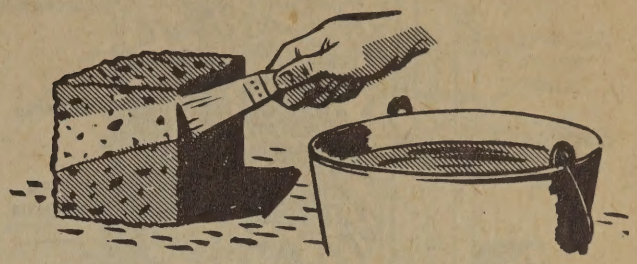
1. Carefully smooth face surface and mark outline of chunk.

2. Excavate around and in back of chunk. Shape chunk roughly with butcher knife.

3. Cut off chunk and carefully remove from hole.

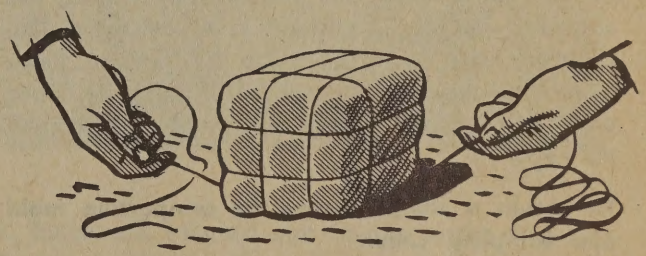
To seal chunk after removing it from hole:

1. Trim and shape rough edges with butcher knife.



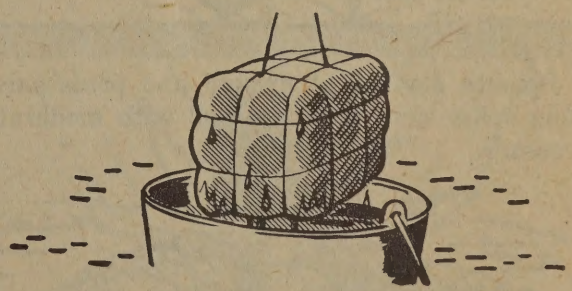
2. Apply three coats of paraffin with paint brush. Allow each coat to cool and become firm before applying next coat.

NOTE: This gives adequate protection for strong samples that are to be used within a few days. Samples that are weak or may not be used soon require additional protection.

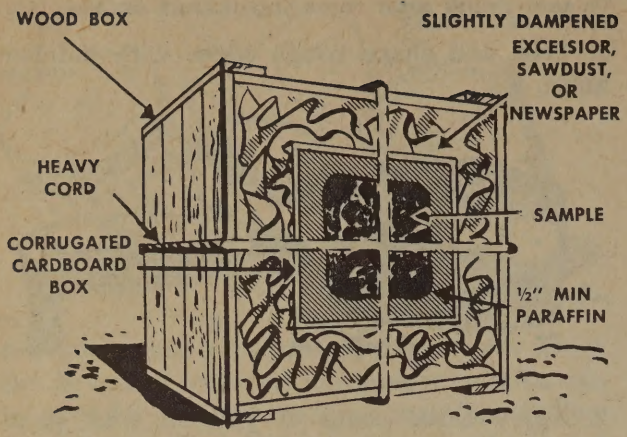


3. Wrap with cheesecloth or other soft cloth. If cloth is not available, reinforce with several loops of friction tape or twine.

4. Apply three more coats of paraffin.



NOTE: A better method is to dip entire sample in melted paraffin after first brush coat is applied. This requires a large container and more paraffin, but gives a more uniform coating. By repeated dipping, paraffin can be built up to a minimum $\frac{1}{8}$-inch thickness. Samples that are to be shipped require additional protection.

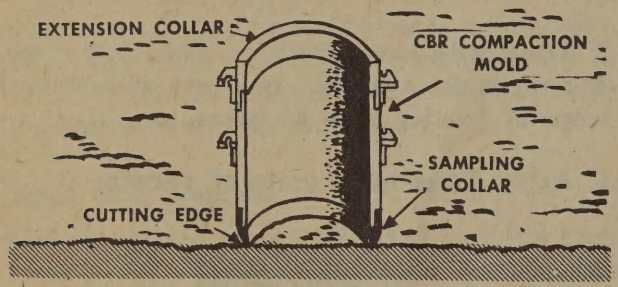


Place chunk in small box and pack as shown, or apply many coats of cloth and paraffin.

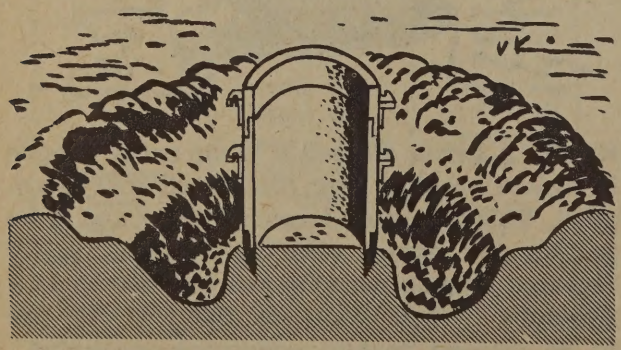
Cylinder Samples

In soft fine-grained soils, cylinder samples for undisturbed CBR or density tests may be taken directly in a CBR compaction mold using the sampling collar. Cylinder samples may also be taken with an ordinary tin can, a short piece of pipe, or any other metal container. For other soils, it is better to use a split mold as described on page 79.

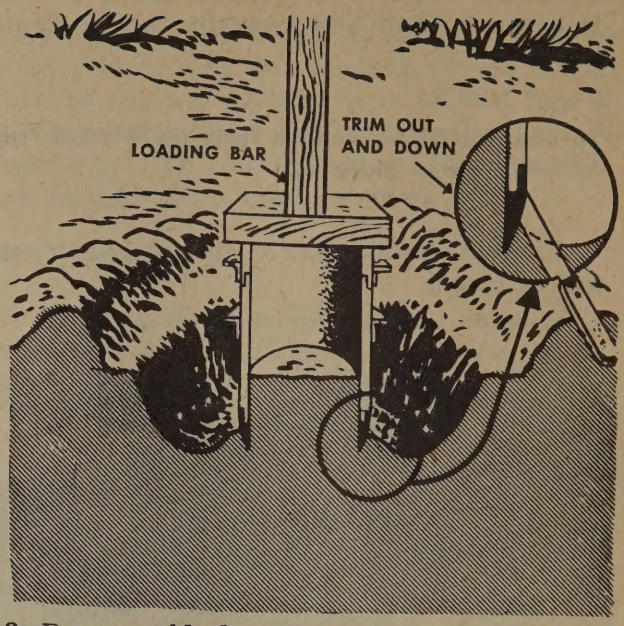
To obtain a sample using the compaction mold and sampling collar:



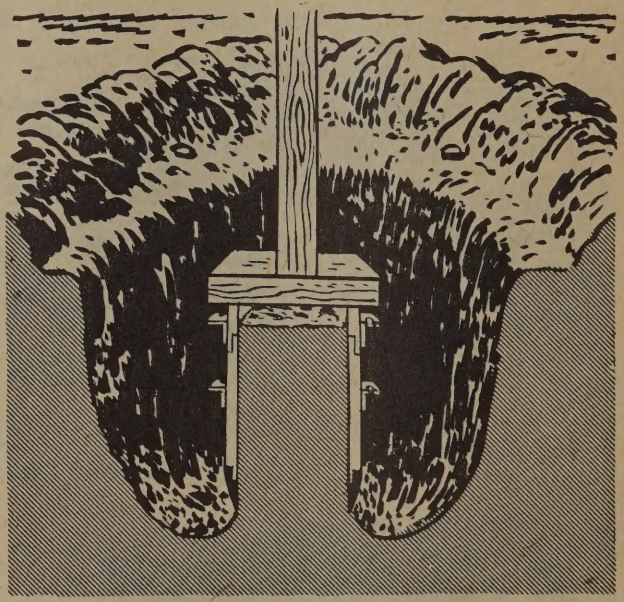
1. Smooth surface of ground and press sampling collar and mold into soil with moderate pressure.



2. Excavate trench around cylinder.

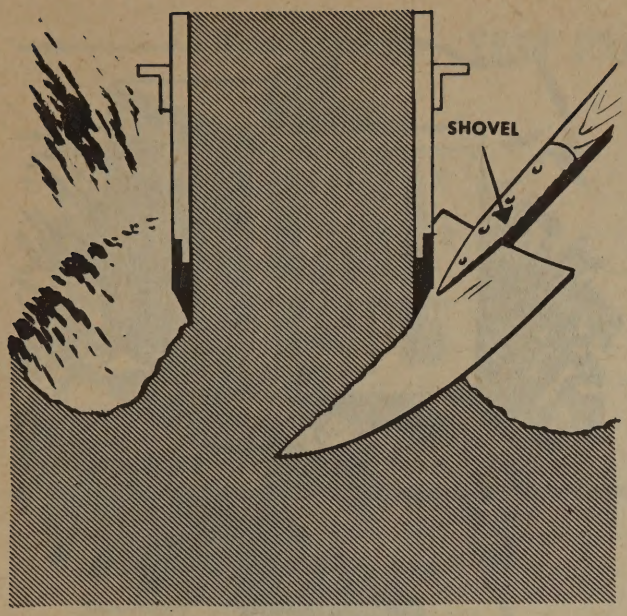


3. Press mold down over soil firmly, using loading bar if necessary. Carefully trim soil away from sampling collar with knife. Cut downward and outward to avoid cutting into sample. The actual cutting to size is done with sampling collar.



4. Excavate trench deeper and repeat process until soil penetrates well into extension collar.

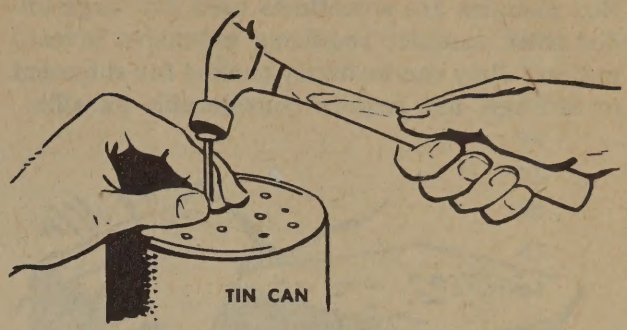
NOTE: If stones interfere, pick them out carefully and backfill with soil. Record this fact in log of sample whenever this is done.



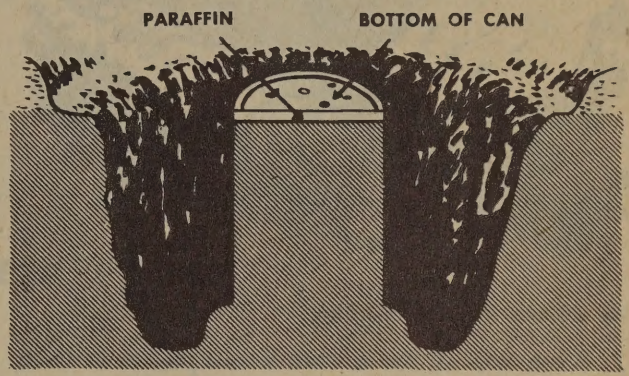
5. Cut off sample at bottom of mold with shovel, butcher knife, or wire saw and remove from hole.
6. Remove upper collar and trim top surface of sample; then turn mold upside down, remove sampling collar, and trim bottom. The top and

bottom surfaces must be trimmed level with ends of mold. Protect ends with wood discs and tape around edges.

Any large size cylindrical fruit can with top removed can be used for obtaining cylinder samples.



1. Punch holes in bottom of can.



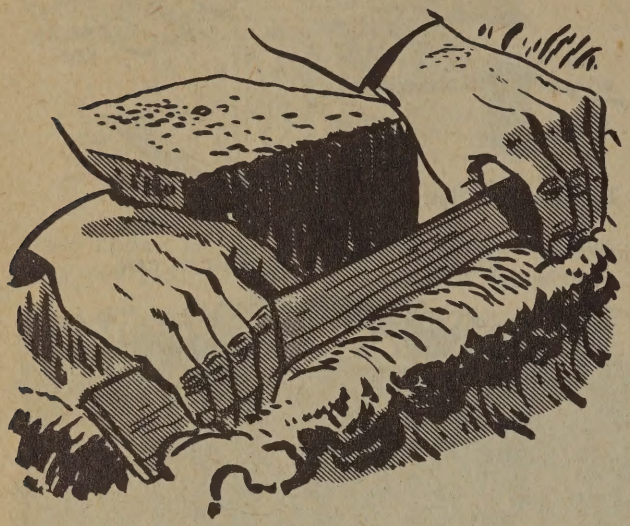
2. Excavate around can in the same way as for compaction mold and press down until soil penetrates to bottom of can.

3. Pour paraffin in holes and seal bottom of can. Cut off sample with butcher knife and remove from hole.

4. Cut surface about ½-inch below top of can and fill with paraffin.

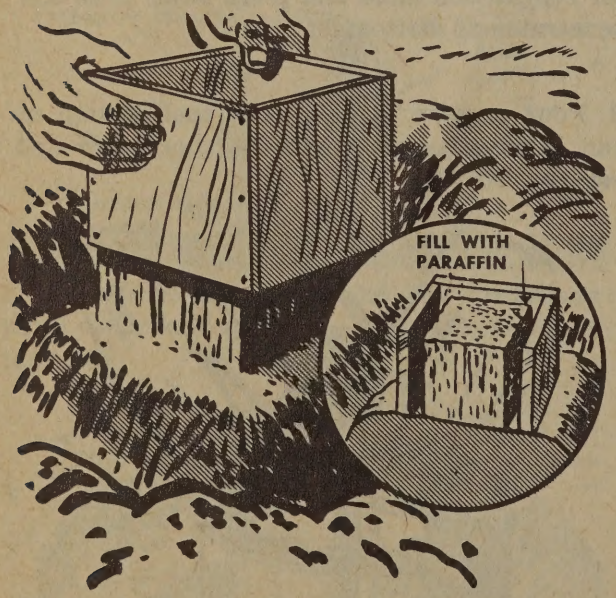
Box Samples

Box samples are sometimes used for large undisturbed samples requiring extensive investigation. They can be firmly packed for shipment or storage, but require considerable paraffin.

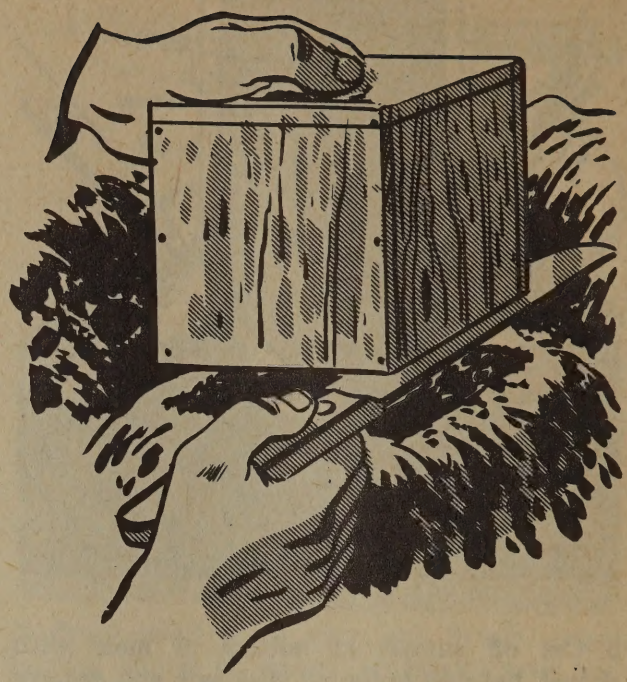


To obtain a box sample:

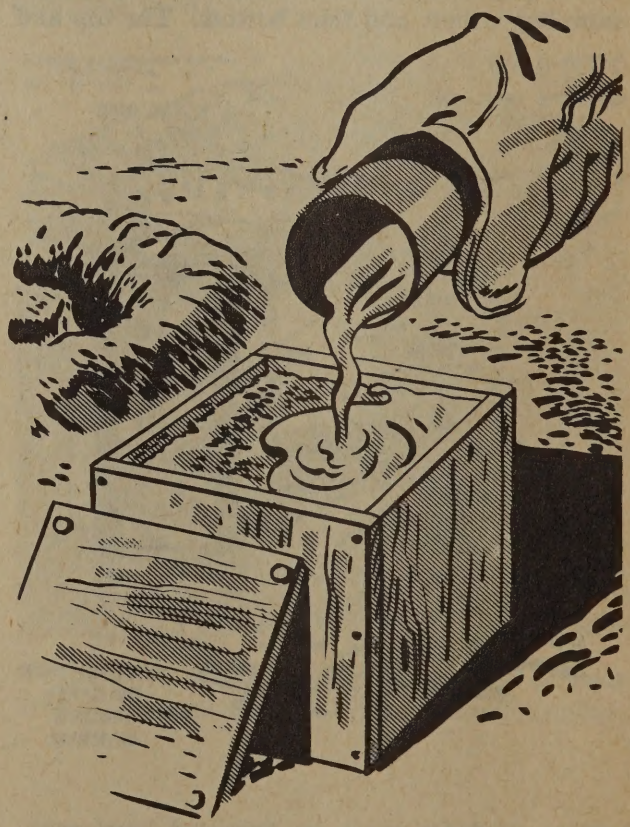
1. Excavate as for a chunk sample, then trim sample to size slightly smaller than box.



2. Remove top and bottom from box and place over sample.
3. Fill sides with paraffin, then pour paraffin over top of sample and replace bottom.



4. Cut off sample, remove box containing sample from hole, and turn right side up.



5. Trim surface of sample and seal with melted paraffin, then replace lid.

TEST PROCEDURES

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GENERAL

Soil tests are made (1) for general classification of soils, (2) for construction control, and (3) for determining soil strength.

General Tests

General tests are used to identify soils so they can be properly described and classified. General tests described in this bulletin are:

- Specific-gravity test
- Mechanical analysis
- Plasticity tests

Control Tests

Control tests are used to assure that soils are properly compacted during construction so design standards are met in the field. The control tests described are:

- Moisture-content test
- Unit-weight determination
- Compaction test for optimum moisture content

NOTE: The moisture-content test is listed as a control test, although it is also an essential part of most classification and strength tests.

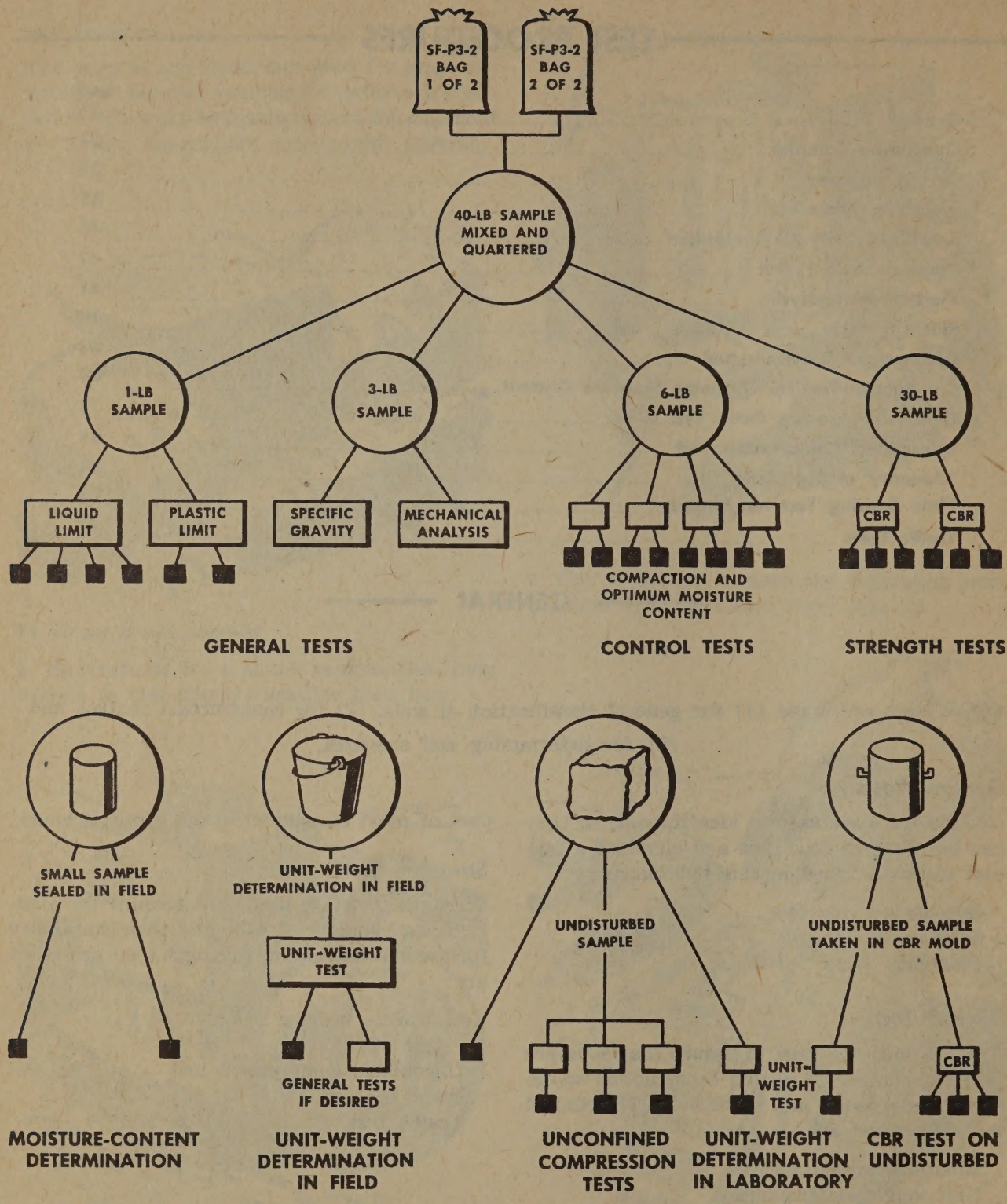
Strength Tests

Strength tests are used to determine the load-carrying capacity of soils and their suitability for use in construction. Strength tests described are:

- California bearing ratio test (CBR)
- Unconfined compression test
- Plate bearing test
- Traffic test

Quantity of Soil Required for Tests

The quantity of material required for the various tests is illustrated on page 32. All tests are not required on each sample.


SF-P3-2 BAG 1 OF 2
SF-P3-2 BAG 2 OF 2
40-LB SAMPLE MIXED AND QUARTERED
1-LB SAMPLE
3-LB SAMPLE
6-LB SAMPLE
30-LB SAMPLE
LIQUID LIMIT
PLASTIC LIMIT
SPECIFIC GRAVITY
MECHANICAL ANALYSIS
CBR
CBR
COMPACTION AND OPTIMUM MOISTURE CONTENT
GENERAL TESTS
CONTROL TESTS
STRENGTH TESTS
SMALL SAMPLE SEALED IN FIELD
UNIT-WEIGHT DETERMINATION IN FIELD
UNIT-WEIGHT TEST
GENERAL TESTS IF DESIRED
UNDISTURBED SAMPLE
UNDISTURBED SAMPLE TAKEN IN CBR MOLD
UNIT-WEIGHT TEST
CBR
MOISTURE-CONTENT DETERMINATION
UNIT-WEIGHT DETERMINATION IN FIELD
UNCONFINED COMPRESSION TESTS
UNIT-WEIGHT DETERMINATION IN LABORATORY
CBR TEST ON UNDISTURBED
SYMBOLS
RAW MATERIAL
TEST AS INDICATED
MOISTURE-CONTENT TEST

QUARTERING SAMPLES

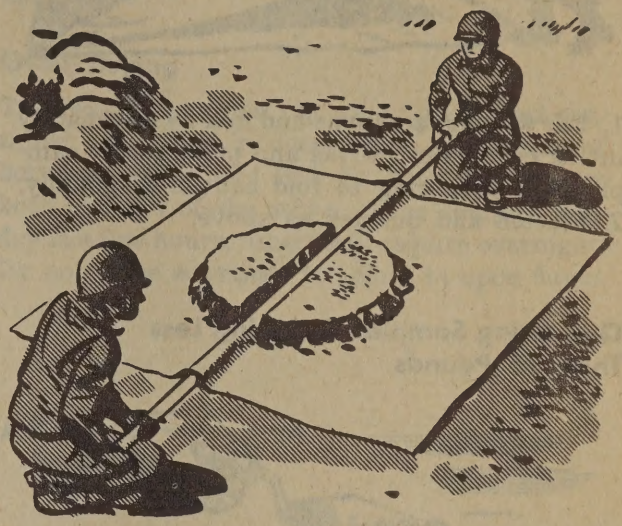
The process of reducing a representative sample to a convenient size, or of dividing a sample into two or more smaller samples for testing, is called quartering.

Quartering Samples Weighing Over 100 Pounds

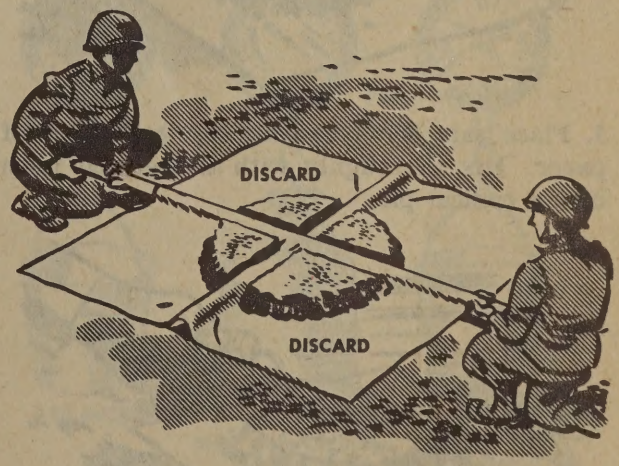
1. Mix and pile sample on canvas. Place each shovelful in center of cone so soil runs down equally in all directions to mix the sample.

2. Flatten cone with a shovel, spreading material to a circular layer of uniform thickness.

3. Insert stick or pipe under center of pile (under canvas) and lift both ends, dividing sample into two parts. Remove stick, leaving canvas in folded position.



4. Insert stick under center of pile at right angles to first division and again lift both ends, dividing sample into four parts.



5. Discard two diagonally opposite quarters, being careful to clean fines from canvas.
6. Remix remaining material by taking alternate shovelfuls from each quarter. Repeat quartering process until sample is reduced to desired size.

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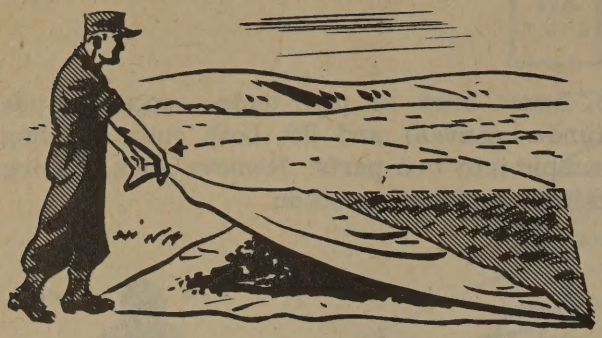
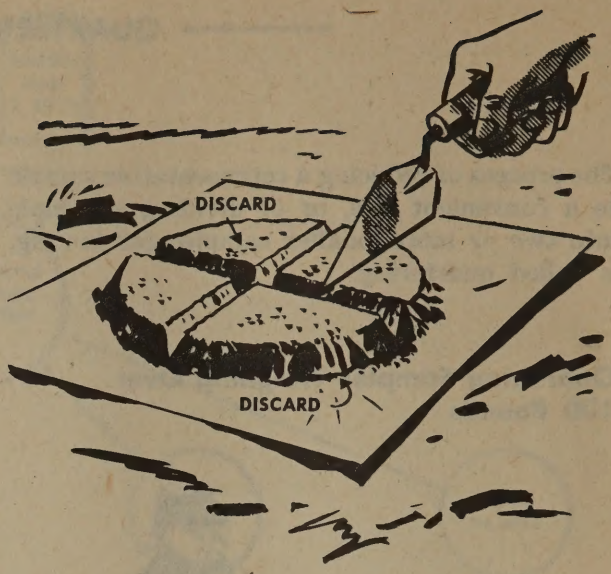
Quartering Samples Weighing 25 to 100 Pounds



1. Pile sample on canvas and mix by alternately lifting corners of canvas and pulling over sample as if preparing to fold canvas diagonally.
2. Flatten and quarter as above.



3. Separate into quarters with trowel and discard diagonally opposite quarters.

Quartering Samples Weighing Less Than 25 Pounds

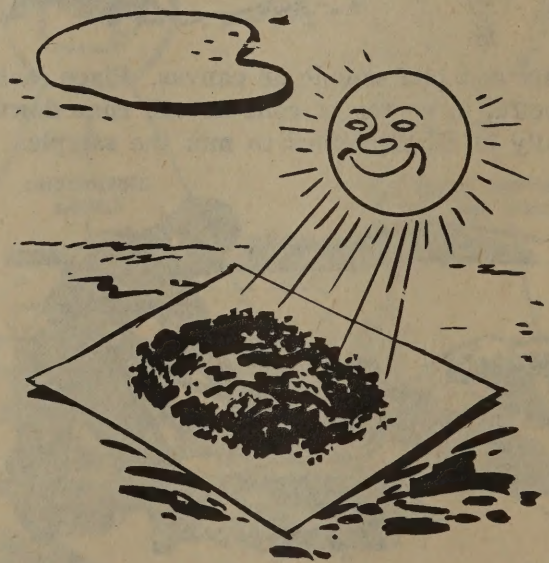
1. Place sample on canvas or clean sheet of paper. Mix thoroughly with trowel and form into a conical pile.

2. Flatten cone by pressing downward with trowel.

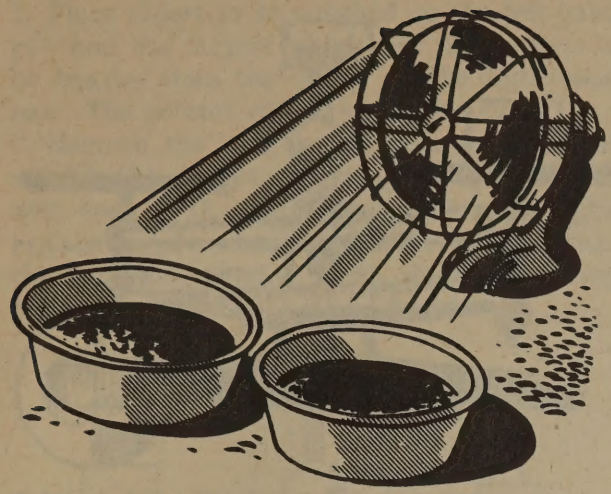
DRYING SAMPLES

All samples used for testing must be air- or oven-dried as specified in the various test procedures.

Air Drying



To air-dry material, place it in pans or spread it on a canvas and expose it to direct rays of sun or to a draft. Frequent agitation or stirring speeds up the drying.



In dry atmosphere, the material also dries readily inside the laboratory or in the shade. A fan blowing air over the sample greatly increases the rate of evaporation.

For semipermanent laboratories, drying racks or shelves should be built on the wall above the oven where warm air circulates (page 20).

When drying time is limited and in humid atmosphere, it may be necessary to air-dry the sample by placing in the oven with the temperature regulated between 150° F and 180° F. This temperature can be maintained by using only one burner of the stove and adjusting the flame low.

Oven Drying

To oven-dry samples, put soil in uncovered container and place in oven which is maintained between 220° F and 250° F. This will require both burners of the stove. Some samples may dry in a few hours, others will require overnight. Do not place container too close to open flame.

WEIGHING MATERIALS

Four scales or balances are included with the set. Use the one best suited for the purpose, depending on the weight of the object and the accuracy required.

ITEM	CAPACITY	ACCURACY
40-lb spring balance	40 lb	0.1 lb
60-lb spring balance	60 lb	0.1 lb
Torsion balance	4,500 gm	5 gm
Triple-beam balance	200 gm	0.01 gm

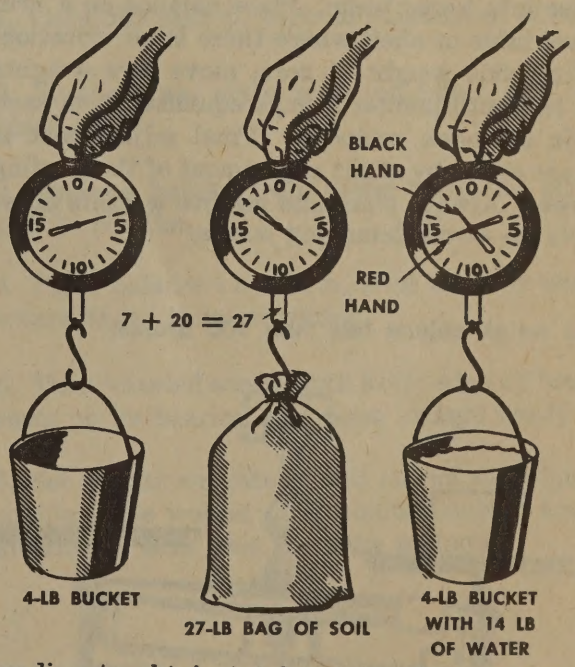
NOTE: If accuracy to 0.1 gram is desired with the torsion balance, cut small weights from nails or small metal strips and calibrate them on the triple-beam balance.

Use of Spring-balance Scales

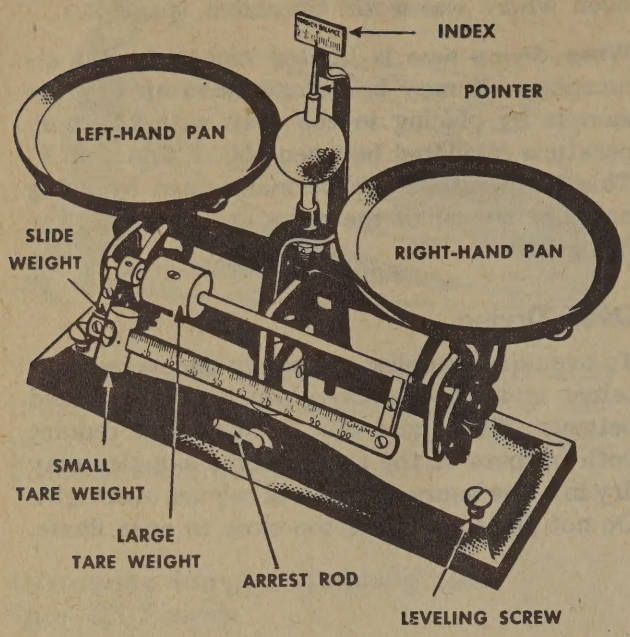
Attach object to hook and suspend scales by holding top ring.

For objects weighing less than 20 pounds, read the weight directly on circular dial.

For objects weighing more than 20 pounds, add 20 or 40, as indicated by slide scale, to dial reading to obtain total weight. If object is to be weighed in a container, first suspend container, then set red hand on dial to indicate zero when black hand indicates tare weight. Red hand then indicates net weight of object and black hand the gross weight of container and object.

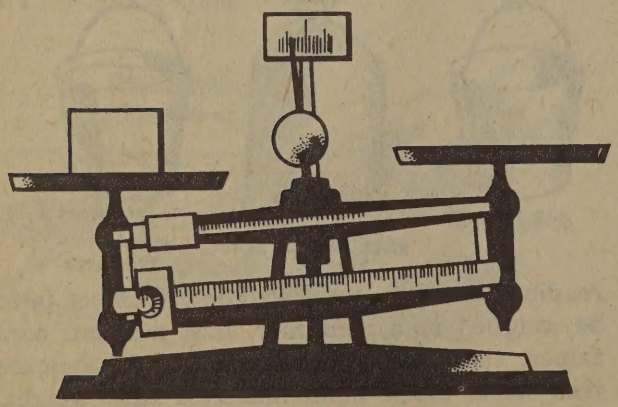


Use of Torsion Balance

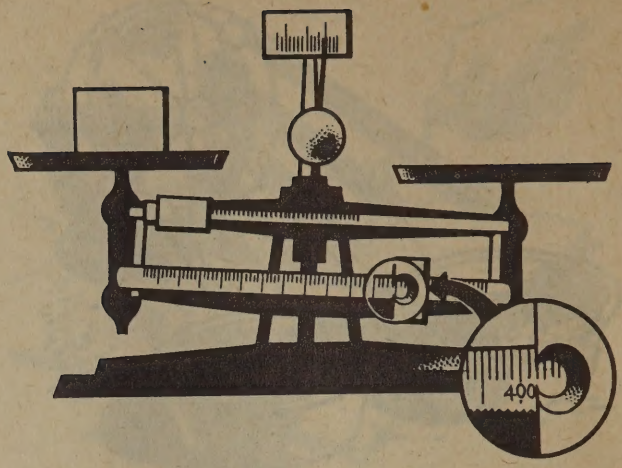


To set up the balance, lift from box and unlock scale by removing small plate from underneath base. Take out two screws projecting through base into lower beam. Place balance on a firm level table or shelf where there is no vibration. With slide weight at zero, move tare weights to left until pointer swings equidistant on each side of index midpoint. Final adjustment is made easier by slight adjustment of the leveling screws. Always place and remove weights carefully to avoid damaging scales.

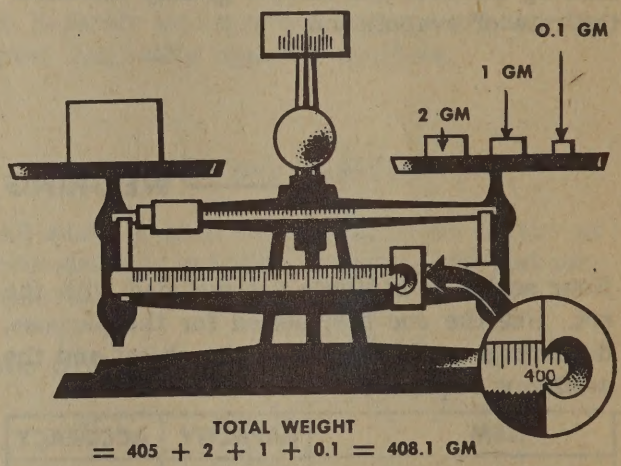
To weigh objects less than 500 grams:



1. Place object to be weighed on the left-hand pan. Pointer will swing to the left.



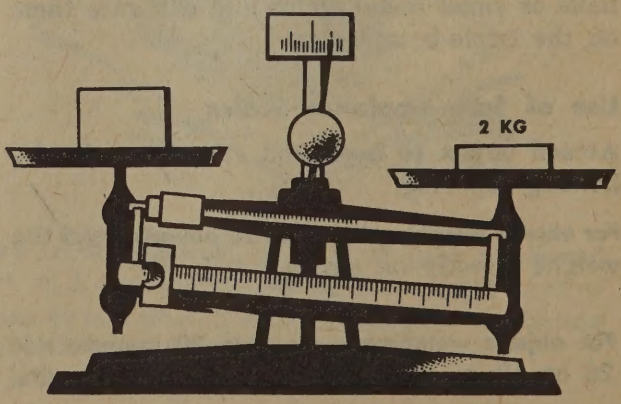
2. Move slide weight to right until pointer swings to the right. Then move slide weight one notch (5 gm) to left.



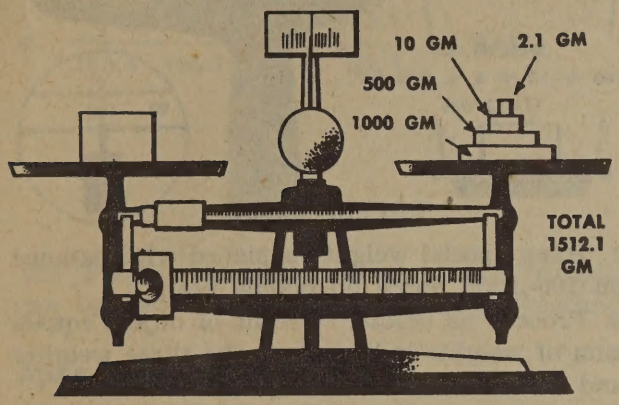
TOTAL WEIGHT
= 405 + 2 + 1 + 0.1 = 408.1 GM

3. Add small weights to right-hand pan until pointer swings equidistant on each side of index midpoint. Total weight is sum of small weights plus weight indicated on scale.

To weigh objects more than 500 grams:

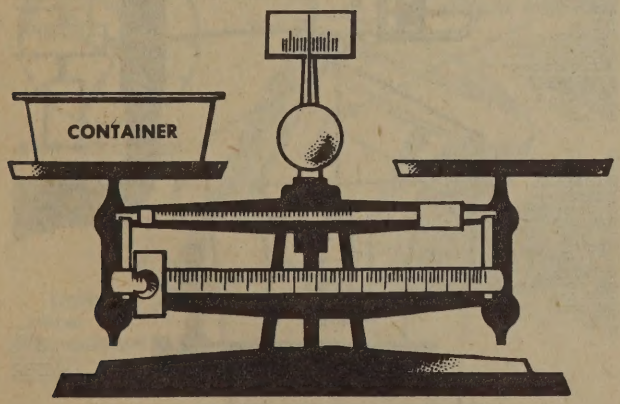


1. Place object to be weighed on the left-hand pan and the largest weight, or one known to be heavier than the object on the right-hand pan. The pointer will swing to the right.
2. Remove the weight and replace with next smaller one. If pointer swings to left, proceed with step 3. If pointer again swings to right, replace weight with next smaller weight until the heaviest weight which does not swing pointer to right is found.



3. Add the next smaller weight to the right-hand pan and continue as before. Repeat until pointer swings equidistant on each side of index midpoint. Add up total weights on right-hand pan.

To weigh object in containers:

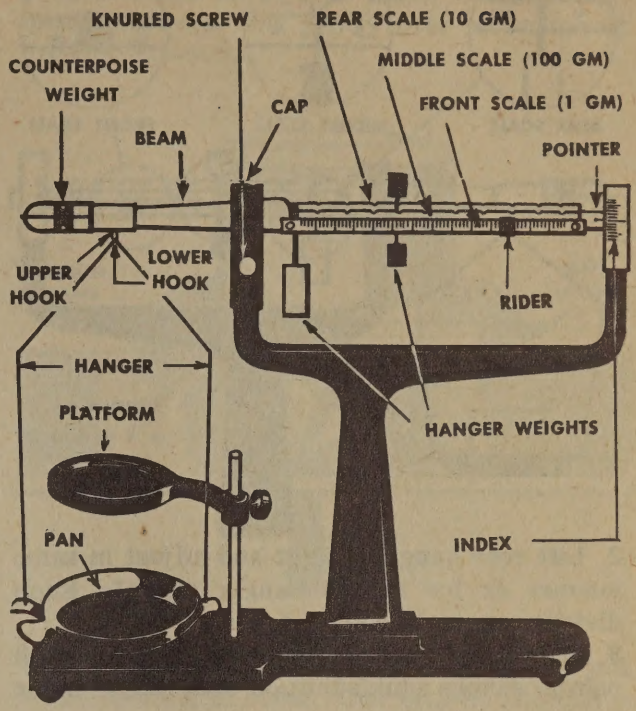


1. Place container on left-hand pan.

2. Slide large tare weight to right until scales are balanced.

3. Place object in container and proceed as above.

Use of Triple-beam Balance



To set up the balance:

1. Carefully take all parts of balance out of box.

2. Remove cap, place beam on pillar, and replace cap.

3. Suspend hanger from upper hook and place pan in position.

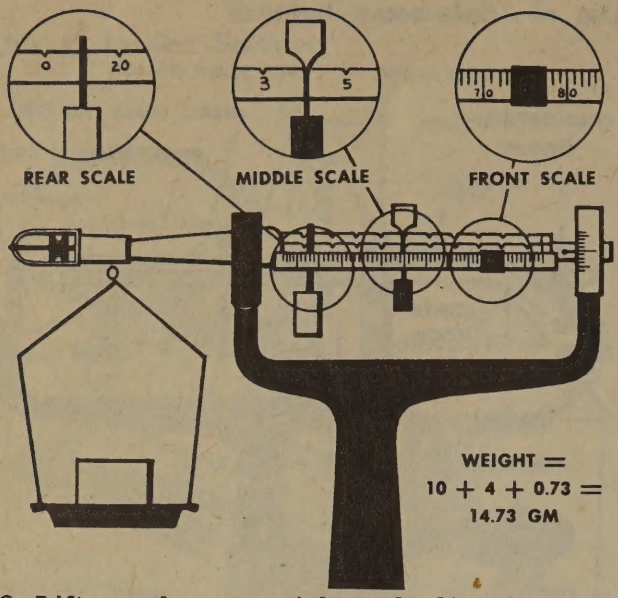
4. Place balance on a firm, level table or shelf where there is no vibration.

5. Turn knurled screw until knife edge of beam rests on its bearing and beam swings freely.

6. Set hanger weights at zero marks and adjust counterpoise weight until pointer swings equidistant on each side of index midpoint.

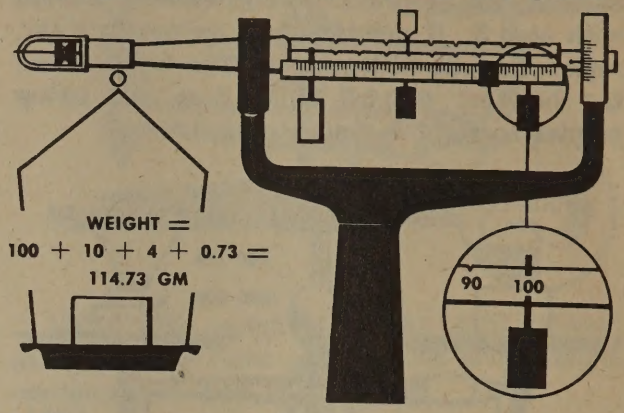
To weigh objects less than 100 grams:

1. Place object to be weighed in pan and shift middle hanger weight to right until placing it in the next notch causes pointer to drop below index midpoint. Each division on scale equals 10 grams.



2. Lift rear hanger weight and adjust in same manner as for middle hanger weight. Each division on scale equals 1 gram.
3. Slide front rider to right with pencil until pointer swings equidistant on each side of index midpoint. Each small division on scale equals 0.01 gram.
4. Total weight equals sum of weights indicated by three scales.

To weigh objects between 100 and 200 grams:



1. Hang special weight furnished with balance on 100-gram notch on middle beam.
2. Proceed as before. Weight of object equals sum of weights indicated by the three weights and the rider.

SPECIFIC-GRAVITY DETERMINATION

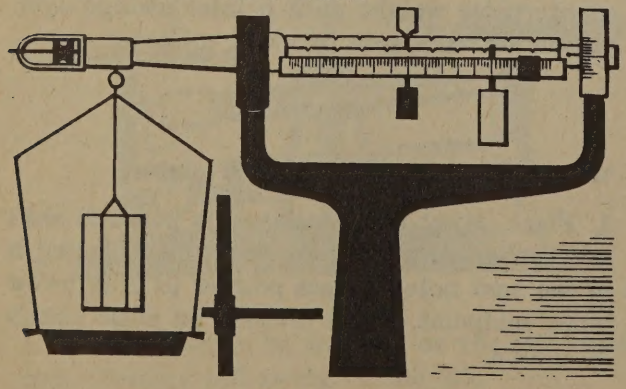
Equipment for determining specific gravity is not included in the set. However, it can be easily improvised from available equipment. The procedure to be used depends on the size and type of sample.

INDIVIDUAL STONES

The specific gravity of individual stones weighing less than 200 grams can be determined by weighing on the triple-beam balance. Usually the specific gravity of stones with their natural moisture content is required.

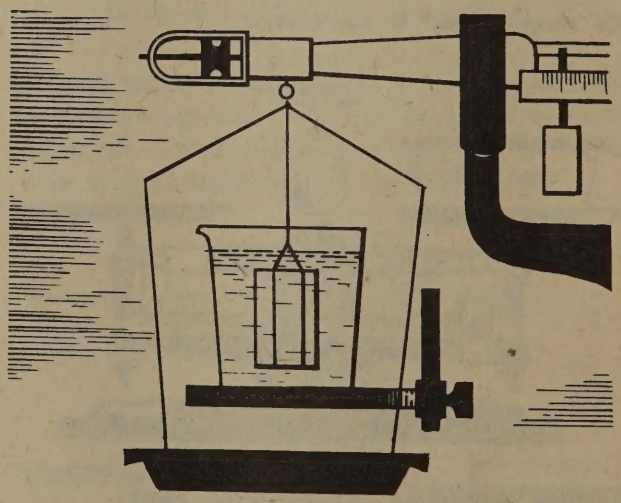
Apparatus Required

Triple-beam balance
Light cord or thread
Small can to hold water



Procedure

1. Loop a small thread around stone and hang from lower hook on triple-beam balance. Weigh to nearest 0.1 gram.



2. Place small can of water on platform, immerse object in water, and reweigh to nearest 0.1 gram.
3. Calculate specific gravity of stone as shown in sample calculation. If cord or thread is very light, its weight can be neglected.

Sample Calculation

Wt of stone in air ---------- **163.4 gm**

Wt of stone in water ---------- **100.7 gm**

Specific gravity

$$= \frac{\text{wt stone in air}}{\text{(wt stone in air) - (wt stone in water)}}$$

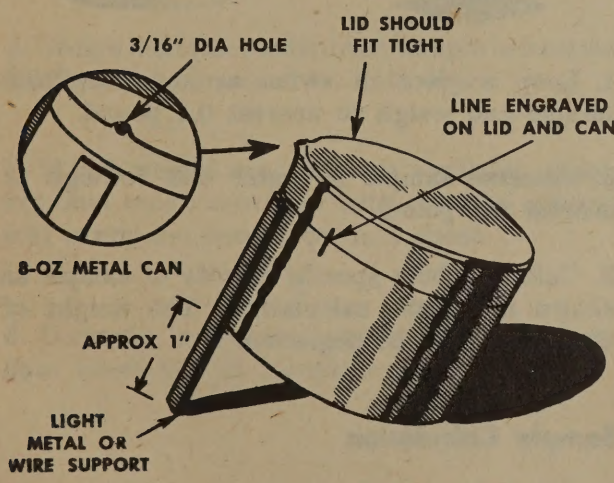
$$= \frac{163.4}{163.4 - 100.7} = \frac{163.4}{62.7} = 2.61$$

SOIL SAMPLES

The average specific gravity of soil samples can be determined by the following method.

Apparatus Required

Torsion balance
Gasoline stove
Constant-volume can
Pan
Battery filler

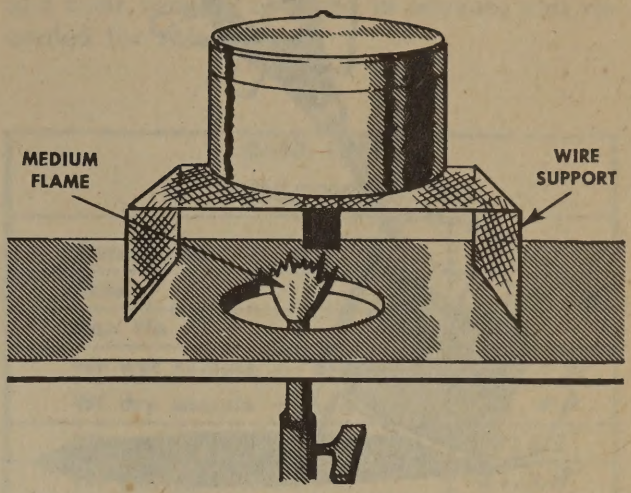


Procedure

1. Weigh constant-volume can with lid to nearest 0.1 gram.

2. Place oven-dry sample (50 to 150 grams) in can and weigh to nearest 0.1 gram.

3. Add water to fill can about one-half full, close cover, and boil gently over stove for at least 30 minutes.



NOTE: Boil gently so soil does not splash out small opening in cover. Can may be suspended several inches above flame, placed on hot metal plate, or placed in hot oven. For clean sands, boiling can be omitted and a thorough stirring with a rod substituted.

4. Remove can from stove and immerse in a pan of water at room temperature. Allow to cool.

5. Remove can from bath, holding it with hole on top, dry outside with towel, and carefully fill with water to level of rim around hole. Weigh to nearest 0.1 gram.

NOTE: If the lid does not fit tight enough to prevent water from leaking out, either use a stiff waterproof grease or seal by wrapping with tape. The weight of grease or tape used is included in all weight determinations.

6. Empty contents of can, rinse clean, and refill with water from pan used to cool sample. Dry outside of can and reweigh to nearest 0.1 gram.

7. Compute specific gravity of sample as shown in sample calculation.

Wt of can _____ **76.1 gm**
Wt can + dry soil _____ **222.6 gm**
Wt can + soil + water _____ **406.4 gm**
Wt can + water _____ **315.1 gm**
Wt dry soil = (wt can + dry soil) - (wt of can)
= 222.6 - 76.1 = 146.5 gm

Specific gravity =

$$\frac{\text{wt dry soil}}{(\text{wt dry soil}) + (\text{wt can} + \text{water}) - (\text{wt can} + \text{soil} + \text{water})}$$

$$= \frac{146.5}{146.5 + 315.1 - 406.4} = \frac{146.5}{55.2} = 2.65$$

Use of Pycnometer Top

If the pycnometer top illustrated on page 16 is available, the procedure for specific-gravity determination is essentially the same as above, except that a much larger sample is used.

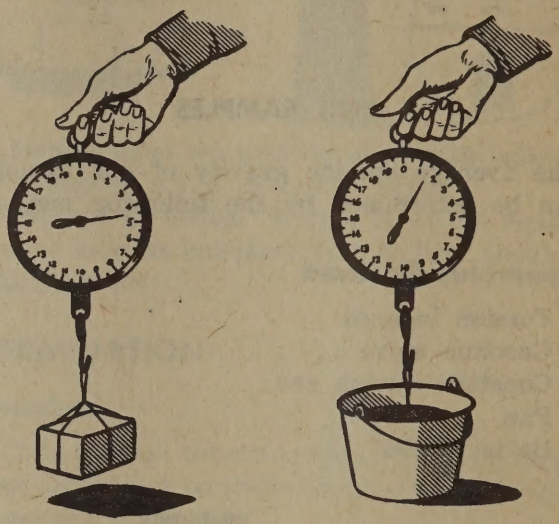
CHUNK SAMPLES

It is sometimes necessary to determine the bulk specific gravity of a paraffined sample either for density test (page 64) or for CBR test (page 71). The bulk specific gravity determined is for the sample with paraffin and not for the sample alone.

Apparatus Required

Spring balance
Bucket
Twine

Procedure



1. Loop a piece of twine around paraffined sample and weigh to nearest 0.1 pound.

2. Immerse sample in water and reweigh to nearest 0.1 pound.

3. Calculate bulk specific gravity of sample as shown in sample calculation. The weight of the twine may be neglected.

Sample Calculation

Wt of sample in air _____ **4.5 lb**
Wt of sample in water _____ **1.6 lb**
Bulk specific gravity =

$$\frac{\text{wt sample in air}}{(\text{wt sample in air}) - (\text{wt sample in water})}$$

$$= \frac{4.5}{4.5 - 1.6} = \frac{4.5}{2.9} = 1.55$$

MOISTURE-CONTENT TEST

The moisture or water content of a soil sample is the ratio of the weight of water contained in the sample to the oven-dry weight of the sample, expressed in percent.

Apparatus Required

Triple-beam balance

Oven	Spatula
Stove	Metal boxes

For average moisture-content determinations, the 4-ounce metal boxes are satisfactory, but much larger or much smaller samples and any suitable container can be used.

Procedure

1. Weigh container with wet sample to nearest 0.01 gram and record on data sheet.

2. Uncover container and place in oven to dry.

3. Remove from oven, replace cover tightly, and set aside to cool to room temperature.

4. Weigh container with dried sample to nearest 0.01 gram and record on data sheet.

5. If tare weight is not already available, clean, dry, and weigh container with cover to nearest 0.01 gram and record on data sheet.

6. Compute moisture content as shown on data sheet and in sample calculation.

NOTE: It is recommended that all containers used for moisture-content tests be numbered and their weights obtained in advance and recorded for reference.

DATA SHEET MOISTURE-CONTENT TEST	
Sample No	SF-P5-3
Date	19 JUNE 45
Can No	19
Wt wet sample + can (gm)	85.55
Wt dry sample + can (gm)	76.90
Wt water (gm)	8.65
Wt can (gm)	41.28
Wt dry sample (gm)	35.62
Moisture content (%)	24.3

Sample Calculation

To calculate the weight of water in sample:

Wt water = (wt wet sample + can) − (wt dry sample + can) = 85.55 − 76.90 = 8.65 gm

To calculate the weight of dry sample:

Wt dry sample = (wt dry sample + can) − (wt can) = 76.90 − 41.28 = 35.62 gm

To calculate moisture content:

$$\text{Moisture content} = 100 \times \frac{\text{wt water}}{\text{wt dry sample}}$$

$$= 100 \times \frac{8.65}{35.62} = 100 \times 0.243 = 24.3\%$$

MECHANICAL ANALYSIS

The determination of grain-size distribution in a soil, called mechanical analysis, is made by a screening process (sieve analysis) for coarse-grained soils, and by a settling process in water (wet mechanical analysis) for fine-grained soils. When both processes are used on the same sample, the test is called combined mechanical analysis.

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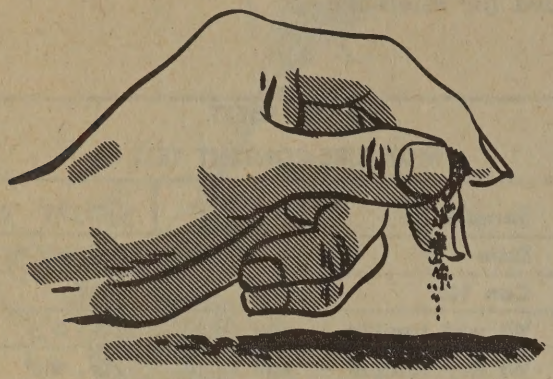
SIEVE ANALYSIS

Depending on the character of the fine material in the sample, a sieve analysis is made either on the entire sample or on the sample after the fines are removed by washing. If need for pre-



washing cannot be determined by visual inspection, oven-dry a moist pat of the material and then examine its dry strength by breaking it up between the fingers. If it can be easily crushed and the fine material powdered by finger pressure, then a sieve analysis can be made without prewashing.

Apparatus Required

Torsion balance	Saucepans
Set of sieves	Gasoline stove
Set of portable screens	Oven
Paint brush	Triple-beam balance

Improvised equipment:

Rubber-Covered pestle (page 17)
Rolling pin (page 17)

Size of Sample

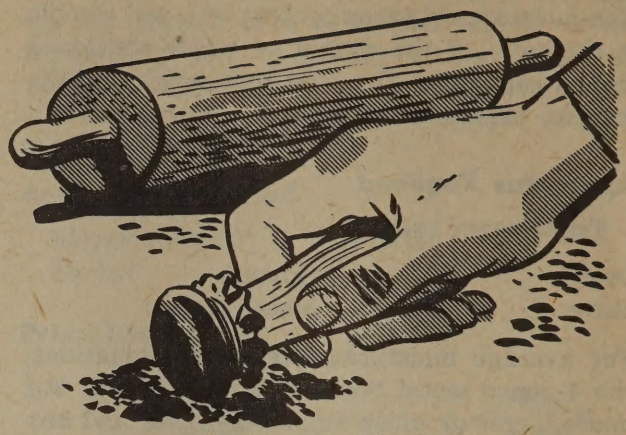
The size of sample required depends on type of soil to be screened.

TYPE	SIZE OF SAMPLE
Fine-grained soil	100-200 grams
Sandy soil	200-500 grams
Gravelly soil	1-3 kilograms

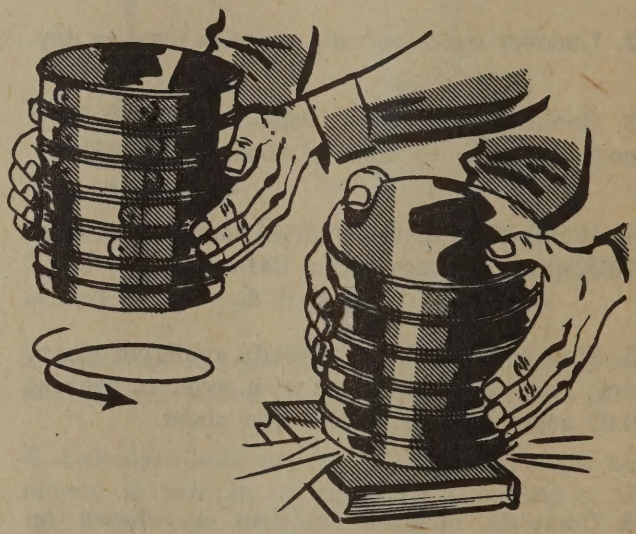
Test Procedure for Sieve Analysis

1. Oven-dry sample.

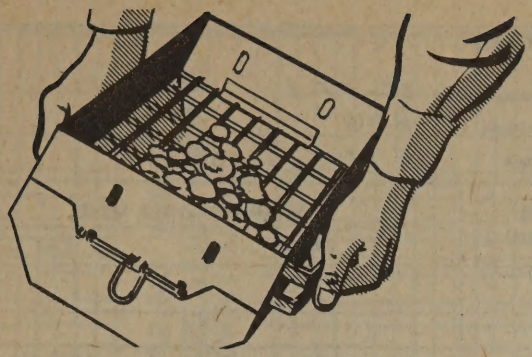
2. Weigh sample after cooling and record weight to nearest gram.



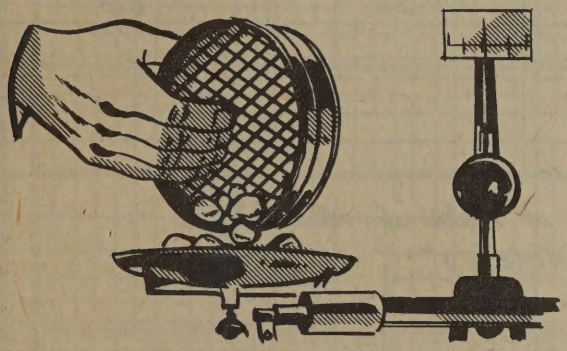
3. Break up lumps of material by rolling with improvised rolling pin on clean, smooth surface. Powder fine material with rubber-covered pestle until thoroughly pulverized.



4. Transfer sample to set of sieves (coarse sieves at top, fine sieves at bottom) with the sieve pan on bottom. Place cover on top and shake the stack vigorously with a horizontal rotating motion. The sieves may be jarred occasionally by dropping lightly on several thicknesses of magazines. Do not drop directly on work bench or table; this will damage sieves. The shaking period depends on the amount of fine material in the sample, but should not be less than 15 minutes for most fine-grained soils.

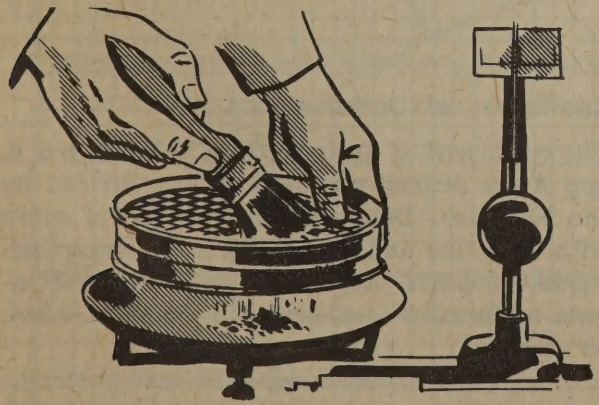


NOTE: Large samples containing many coarse stones should first be screened through the portable screen set. The number and size of screens and sieves to be used depends on the type of soil tested and the purpose of the test. It is often permissible to omit a few of the intermediate sizes, as illustrated by the sample data sheet.



5. Transfer material from largest screen to pan of torsion balance and weigh to nearest 5 grams. Record size of largest particle. Place material in separate container and save until test is completed.

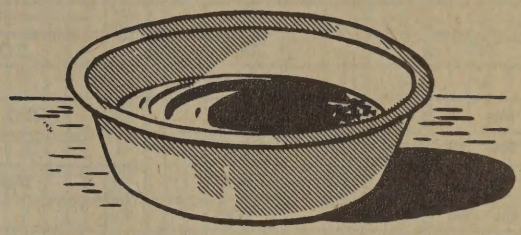
NOTE: For samples weighing less than 500 grams, weigh each fraction on triple-beam balance to nearest gram.



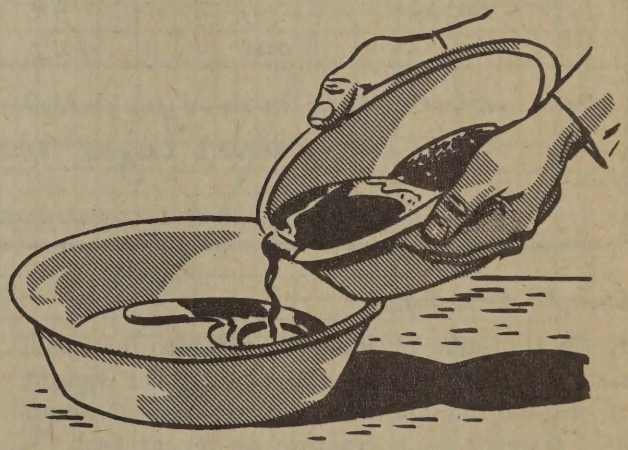
6. Repeat procedure for each successively smaller screen size. Individual stone particles caught in the wire screens should not be forced through screens but should be removed by hand and included with fraction before weighing. The finer sieves should be inverted over the scale pan and brushed clean.

Test Procedure for Sieve Analysis with Prewashing

1. Same as steps 1 to 3 above.



2. Transfer sample to saucepan, fill with enough water to cover material, and let soak until all material is disintegrated. This may require 2 to 12 hours.



3. Agitate sample thoroughly with fingers, then carefully pour off dirty water. Do not wash off any of the visible particles in the bottom of the pan.
4. Add fresh water to pan and repeat washing process until rinse water is clean. The larger stones in the sample may be individually washed and set aside in a separate pan.
5. Oven-dry washed sample and reweigh.
6. Make a sieve analysis of washed sample as in steps 4 to 6 above.

NOTE: The difference in weight between the oven-dry original sample and the oven-dry washed sample is added to the weight of material retained in the pan to determine weight passing No 200 sieve (see data sheet).

DATA SHEET

SIEVE ANALYSIS

Wt of original sample 431 GM
Wt after prewashing 411 GM
Washing loss 20 GM

Sample No SF-P3-2
Initials SDW
Date 19 June 1945

SIEVE OR SCREEN	SIEVE OPENING (MM)	WT RETAINED ON SIEVE (GM)	WEIGHT PASSING SIEVE	
			(GM)	(%)
2"	50.8			
1½"	38.1			
1"	25.4	0	431	100.0
¾"	19.1	20	411	95.4
¼"	6.35			
No 4	4.75	122+4=126	285	66.1
No 10	2.00	121	164	38.1
No 40	0.42	86	78	18.1
No 60	0.25			
No 100	0.149	37	41	9.5
No 200	0.074	15	26	6.0
Retained in pan		6		
Washing loss		20		
Pan total		26		
TOTAL		427		

Remarks: Error = 431 − 427 = 4 gm (added to wt of material retained in No 4 sieve). Largest size particle = 1"

Sample Calculation

1. Obtain sum of weights retained on each sieve and check this total against the weight of original dry sample. If error exceeds about 3%, reweigh each fraction or repeat test.
2. If error is less than 3%, apply numerical value of error to weight of largest fraction.
3. Compute the weight of material passing each sieve. For example:

Wt passing No 4 sieve =

(wt of original sample) − (wt of material retained on No 4 and all larger sieves)

$$431 - (20 + 126) = 431 - 146 = 285$$

4. Compute the percentage by weight of material passing each sieve. For example:

$$100 \times \frac{\text{wt passing No 4 sieve}}{\text{wt original dry sample}} = 100 \times \frac{285}{431} = 66.1\%$$

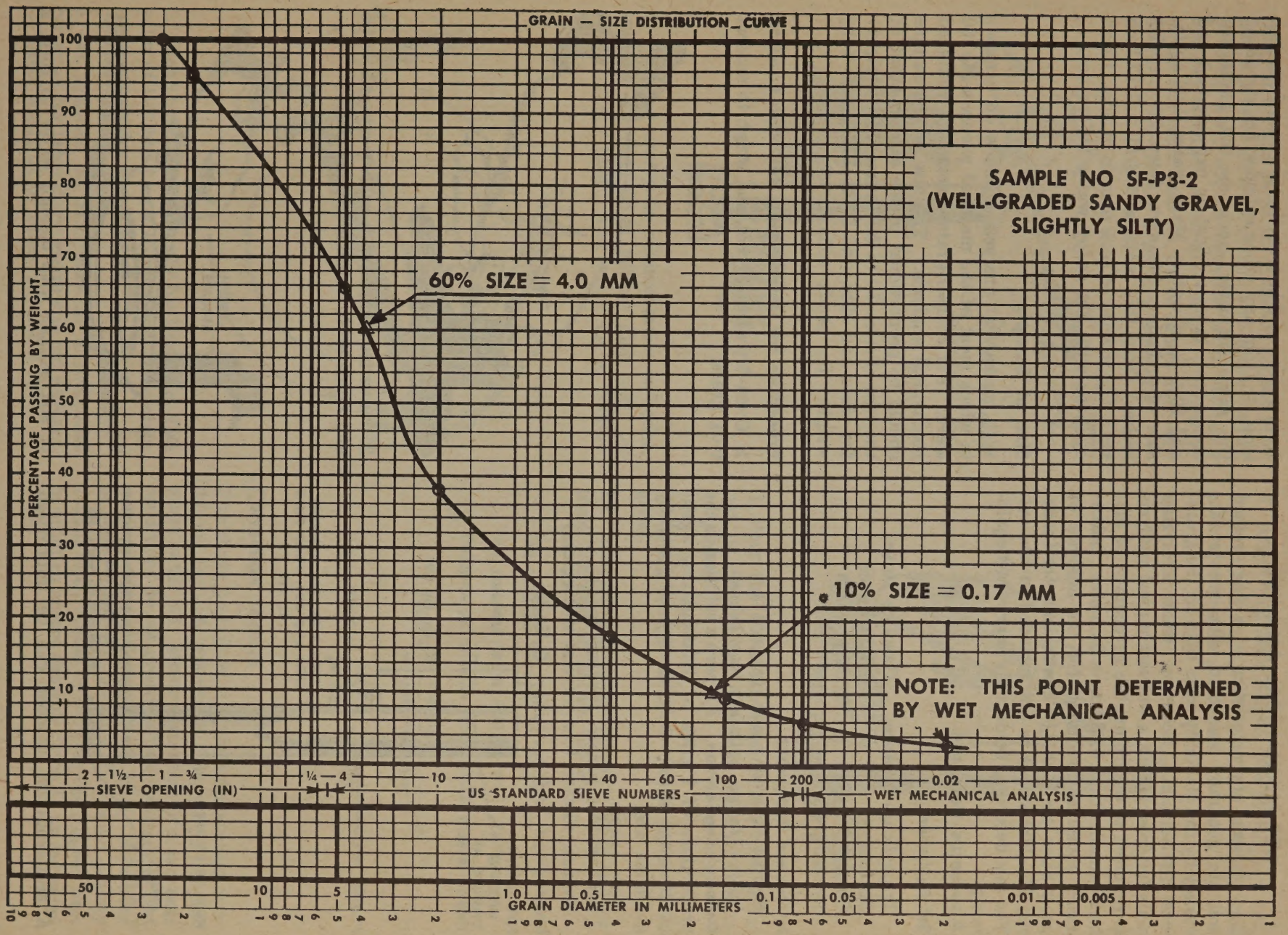
Grain-size Distribution Curve

Plot a grain-size distribution curve on semi-logarithmic paper as shown. Since at least four cycles are often required to plot the curve, two sheets of three-cycle paper furnished with the set may be pasted together.

Coefficient of Uniformity

The coefficient of uniformity (TM 5-255, par 6, app A) is defined as the 60% size divided by the 10% size. Determine intersection of curve with 60% line and note grain size corresponding to this point. Repeat for 10% line and compute uniformity coefficient. In example shown on curve,

$$\text{Uniformity coefficient} = \frac{4.0}{0.17} = 23.5$$


GRAIN — SIZE DISTRIBUTION_CURVE
PERCENTAGE PASSING BY WEIGHT
100
90
80
70
60
50
40
30
20
10
SAMPLE NO SF-P3-2
(WELL-GRADED SANDY GRAVEL,
SLIGHTLY SILTY)
60% SIZE = 4.0 MM
10% SIZE = 0.17 MM
NOTE: THIS POINT DETERMINED
BY WET MECHANICAL ANALYSIS
2
1½
1
¾
¼
4
10
40
60
100
200
0.02
SIEVE OPENING (IN)
US STANDARD SIEVE NUMBERS
WET MECHANICAL ANALYSIS
50
10
5
1.0
0.5
0.1
0.05
0.01
0.005
GRAIN DIAMETER IN MILLIMETERS

WET MECHANICAL ANALYSIS

The physical characteristics of a fine-grained soil are generally identified with greater accuracy by the plasticity tests than by the grain-size distribution. However, when analyzing soils for frost action, a wet mechanical analysis is required to determine the percentage of material smaller than 0.02 mm in diameter. Laboratory equipment required for the analysis of grain sizes less than 0.07 mm in diameter (passing No 200 sieve) is not included in the set. The test described below uses improvised equipment.

Apparatus Required

Set Equipment

Triple-beam balance	Gasoline stove
Spatula	Metal boxes
Oven	Stop watch
100-cc graduated cylinder	

Improvised Equipment

Rubber-covered pestle (page 17)

Sedimentation cylinder (see below)

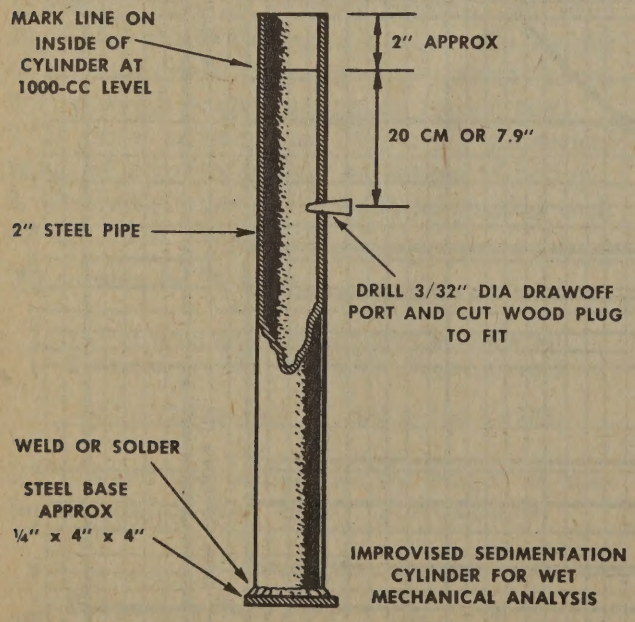
Deflocculating Solution. Prepare a solution in the proportions of 1 gram of deflocculating agent to 20 cc of water. Suitable agents generally available are:

Gum arabic

Sodium bicarbonate (baking soda)

Sodium silicate (commercial waterglass)

Improvised Sedimentation Cylinder


MARK LINE ON INSIDE OF CYLINDER AT 1000-CC LEVEL
2" APPROX
20 CM OR 7.9"
2" STEEL PIPE
DRILL 3/32" DIA DRAWOFF PORT AND CUT WOOD PLUG TO FIT
WELD OR SOLDER
STEEL BASE APPROX ¼" x 4" x 4"
IMPROVISED SEDIMENTATION CYLINDER FOR WET MECHANICAL ANALYSIS

A sedimentation cylinder can be improvised from a piece of 2-inch steel pipe about 24 inches long, or from any other cylinder having about the same diameter, such as the guide for compaction tamper. Seal or cap one end and add 1000 cc of water. Mark water level on inside of cylinder. Measure down 20 cm (7.9 inches) from this mark and drill a 3/32-inch hole. Cut a wood or cork plug to fit hole. Clean cylinder with hot soapy water before use.

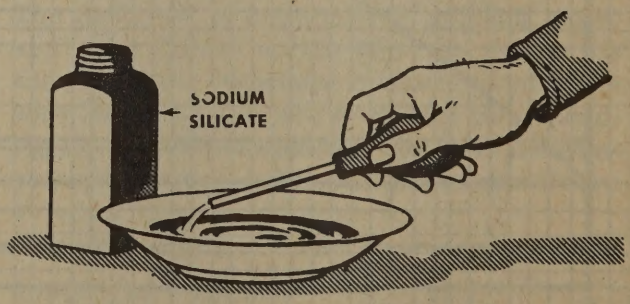
Size of Sample

Wet mechanical analysis is made on samples in which most of the material passes a No 60 sieve. (For coarser-grained soils, see combined mechanical analysis.) The size of the sample should be proportional to the sand content of the soil. Select 30 to 50 grams (dry weight) for clays and silts, and 50 to 150 grams (dry weight) for sandy soils.

Procedure for Determining 0.02-mm Fraction

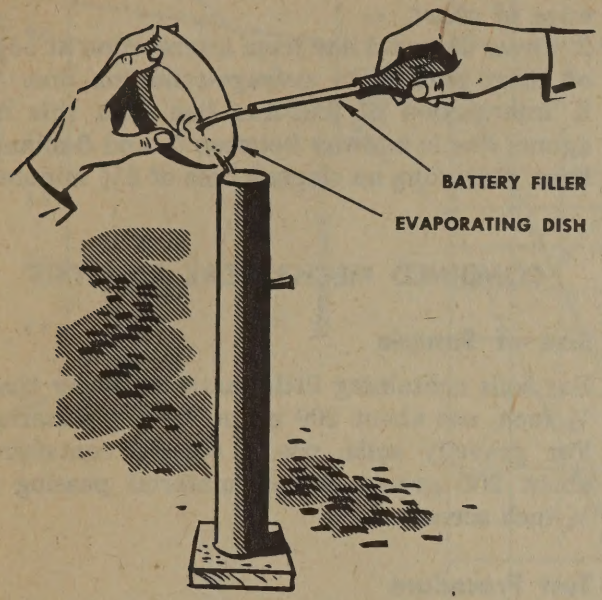
1. Oven-dry sample, cool, and weigh to nearest 0.01 gram.

2. Pulverize sample with rubber-covered pestle and transfer to suitable mixing dish.

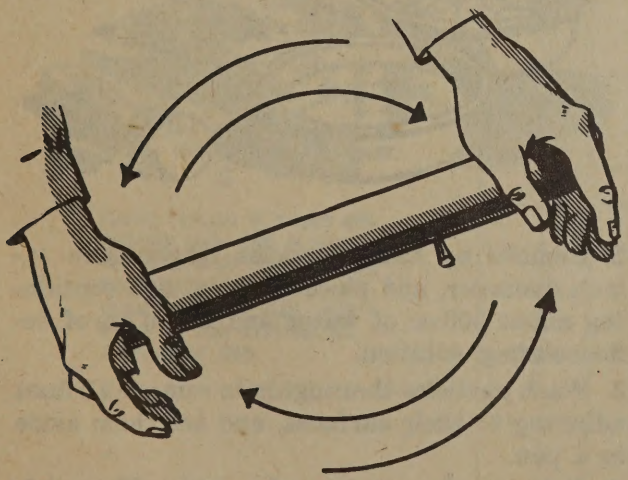


3. Mix sample with enough water to form a

thin slurry, add 20 cu cm of deflocculating solution, and let soak until thoroughly disintegrated. Soaking time should increase with plasticity and dry strength of sample. Allow 2 hours for nonplastic soils and up to 12 hours for very plastic clays having high dry strength.



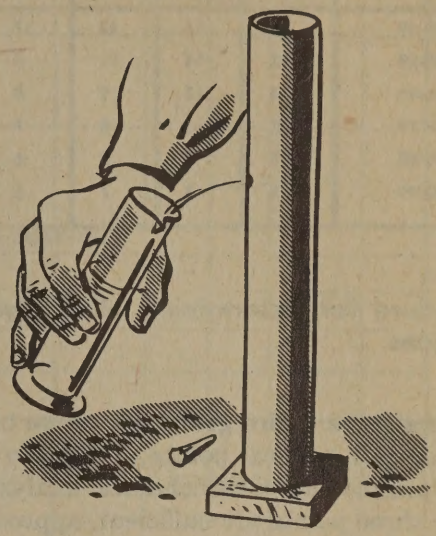
4. Transfer slurry to sedimentation cylinder, washing all fines from mixing dish with jet from battery filler. Add water up to 1000-cc mark.



5. Shake cylinder vigorously for 1 minute. Use palm of left hand as a stopper and completely reverse cylinder end for end.

6. Set cylinder on firm base in a protected corner of the laboratory where it is not exposed to direct sunlight or other one-sided heat.

7. After 9 minutes elapse (see table, page 48), remove plug in drawoff port and collect 100 cc of suspension in graduate.



8. Pour the 100 cc of suspension into a metal box or evaporating dish and place in oven to evaporate.

9. Weigh the oven-dried residue to nearest 0.01 gram.

10. Compute percentage of grain sizes smaller than 0.02 mm as shown below:

Wt original sample = 36.82 gm

Wt residue (from 100 cc) = 1.73 gm

Percentage smaller than 0.02 mm =

$$1000 \times \frac{\text{wt residue}}{\text{wt original sample}} =$$

$$1000 \times \frac{1.73}{36.82} = 47.0\%$$

Correction Factors

The above procedure is correct for average conditions (specific gravity of 2.68, water temperature of 68° F). Minor variations from average conditions do not greatly affect accuracy of test results and may be neglected. Large variations in either water temperature or specific gravity should be corrected by varying the elapsed time in minutes before drawoff (step 7) as indicated below.

ELAPSED TIME (MINUTES)					
WATER TEMPERATURE (°F)	SPECIFIC GRAVITY				
	2.00 to 2.19	2.20 to 2.39	2.40 to 2.69	2.70 to 2.99	3.00 to 3.19
40-49	19	16	13	11	10
50-59	16	14	11	9	8
60-69	14	12	9	8	7
70-79	12	10	8	7	6
80-89	10	9	8	6	5
90-99	9	8	7	6	5

Procedure for Determining other Grain-Size Fractions

To obtain the entire grain-size curve of a fine-grained soil, several points of the curve must be determined by wet mechanical analysis. Generally three points are sufficient, approximately at 0.05, 0.02 and 0.005 mm, to plot the portion of the grain-size curve in this range. The improvised equipment can be used by preparing a separate suspension for each point desired as described above and withdrawing 100 cc of the suspension after an elapsed period determined from the wet mechanical-analysis chart. The percentage of material smaller than each of the sizes selected is then calculated as shown above.

Using Wet Mechanical-analysis Chart

Elapsed time at drawoff for various specific gravities and suspension temperatures to determine the percentage of any desired grain size can be obtained from the chart for wet mechanical analysis shown on opposite page.

Example No 1

To obtain elapsed time for determining percentage of grain sizes smaller than .010 mm under average conditions.

The average-condition line intersects the 0.010-mm line midway between the 30- and 40-minute lines, indicating an elapsed time of 35 minutes.

Example No 2

To obtain elapsed time for determining percentage of grain sizes smaller than 0.02 mm if specific gravity of soil is 2.95 and temperature of suspension chamber is 100° F.

1. Extend line from 2.95 on specific-gravity scale through 100° F on temperature scale to edge of chart.
2. Draw diagonal line from intersection at edge of chart parallel to average-condition line.
3. Intersection of 0.02-mm line with this diagonal line is midway between 5- and 6-minute lines, indicating an elapsed time of 5½ minutes.

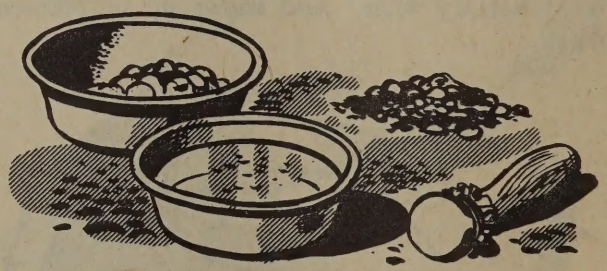
COMBINED MECHANICAL ANALYSIS

Size of Sample

For soils containing little material larger than ¼ inch, use about 200 grams of dry material. For gravelly soils, use a sample containing about 200 grams of dry material passing a ¼-inch screen.

Test Procedure

1. Oven-dry sample and record its total weight.



2. Remove by hand particles larger than ¼-inch diameter, and place them in dish containing about 500 cc of water and 20 cu cm of deflocculating solution.
3. Wash particles thoroughly to remove all fines adhering to their surfaces, and set them aside in a pan.
4. Pulverize fine portion of sample. Place it in the water containing deflocculating solution in which stones were washed, and mix thoroughly.
5. Proceed with wet mechanical analysis as described before, (step 4, page 47) except that the material in sedimentation cylinder is not wasted after withdrawing the 100-cc sample.

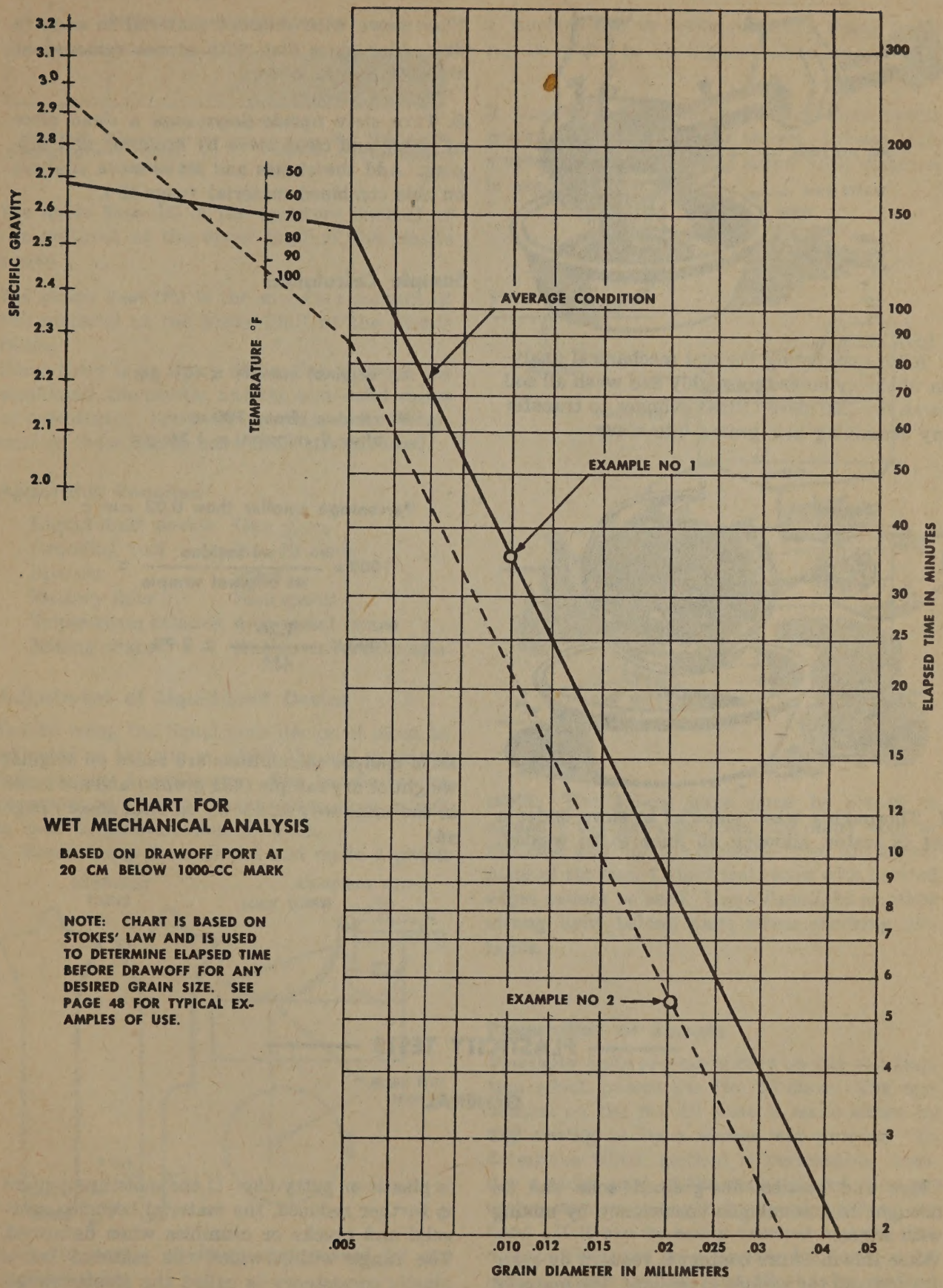
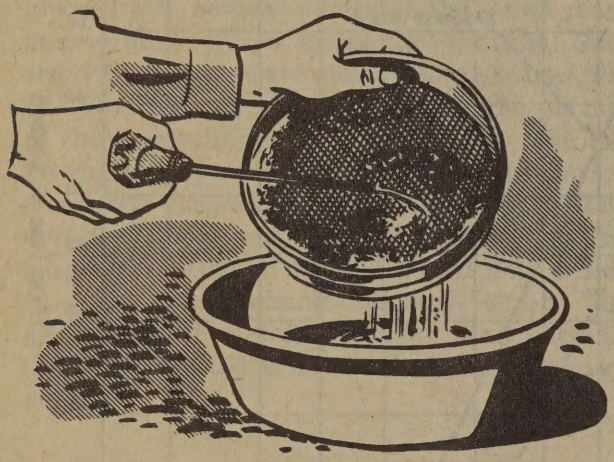


CHART FOR WET MECHANICAL ANALYSIS

BASED ON DRAWOFF PORT AT 20 CM BELOW 1000-CC MARK

NOTE: CHART IS BASED ON STOKES' LAW AND IS USED TO DETERMINE ELAPSED TIME BEFORE DRAWOFF FOR ANY DESIRED GRAIN SIZE. SEE PAGE 48 FOR TYPICAL EXAMPLES OF USE.

6. After completing the wet mechanical analysis, shake cylinder thoroughly and wash all soil into a No 200 sieve. Rinse cylinder to transfer any remaining soil grains into sieve.



7. Thoroughly wash material in sieve under a jet of water, allowing all fines to be wasted. Place sieve with retained material in oven to dry. Also place dish with stones removed at start of test in oven.

8. Turn sieve upside down over a clean piece of paper and clean sieve by brushing and tapping. Add the stones and make sieve analysis on this combined material (page 42).

Sample Calculation

Wt original sample = 431 gm

Wt residue (from 100 cc after 9 minutes) = 1.26 gm

Percentage smaller than 0.02 mm =

$$1000 \times \frac{\text{wt residue}}{\text{wt original sample}} =$$

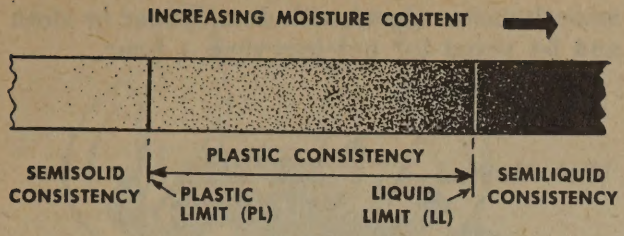
$$1000 \times \frac{1.26}{431} = 2.9\%$$

Sieve analysis calculations are based on original weight of dry sample (431 grams) and are made in the same way as shown on data sheet (page 44)

PLASTICITY TESTS

GENERAL

Clays and related fine-grained soils can be brought to a semiliquid consistency by mixing with water.
When this moisture content is reduced by evaporation and the sample is remixed, the material is plastic or putty-like. If the moisture content is further reduced, the material becomes semisolid and cracks or crumbles when deformed. The range within which the material has a plastic consistency is called the plastic range.



The liquid limit (LL) is the moisture content of the material at the upper limit of the plastic range.

The plastic limit (PL) is the moisture content of the material at the lower limit of the plastic range.

Since there is no sharp distinction between the semiliquid, the plastic, and the semi-solid states of consistency, arbitrary procedures for determining these limits have been standardized.

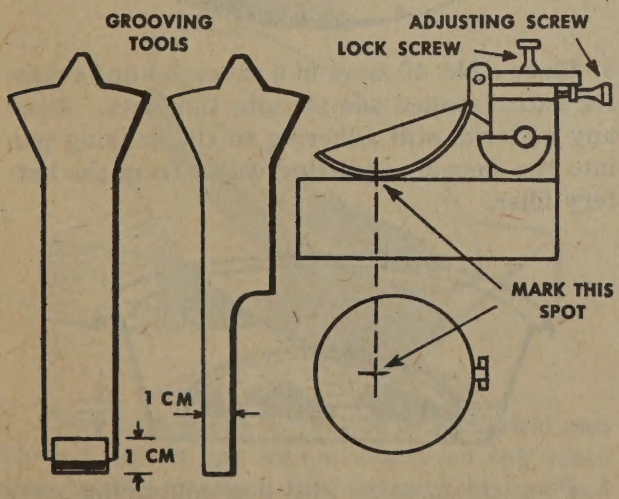
Apparatus Required

Liquid-limit device	Gas stove
Grooving tool	No 40 sieve
Spatula	Oven
Battery filler	Saucepans
Triple-beam balance	4-oz metal boxes
Mixing dishes	Rubber-covered pestle

Adjustment of Liquid-limit Device

Before using the liquid-limit device, it must be adjusted so the cup in which the soil is placed falls exactly 1 centimeter. The handle of the grooving tool has a 1-centimeter gage which is used to measure this distance.

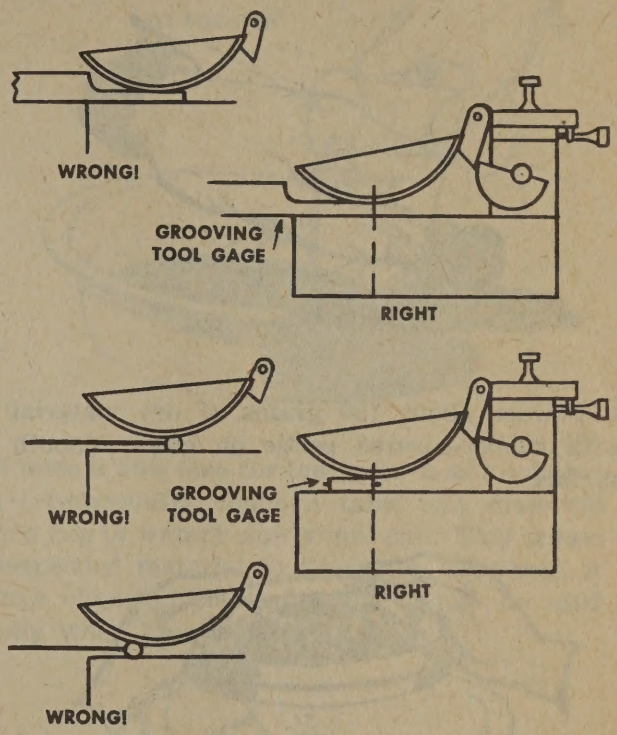
1. Remove cup from device and make a pencil



cross at center of shiny spot caused by cup striking base.

2. Replace cup in device and turn crank until cup is raised to its highest elevation.

3. Insert gage and check distance from pencil marks to base in manner shown. Loosen lock screw and turn adjusting screw until distance is exactly 1 centimeter.



NOTE: The 1.0-cm gage must be placed to measure the distance from the shiny spot to the base and not the distance from the lowest point of the cup. Cylindrical gages with beveled edges cannot be used. Use a flashlight or other strong light behind gage when checking distance.

Preparation of Sample

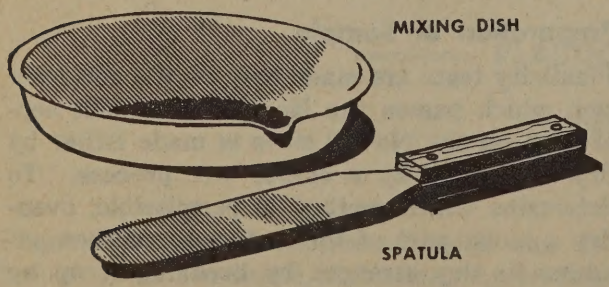
Plasticity tests are made only on the soil fraction which passes the No 40 sieve. The separation on the No 40 sieve is made either by dry sieving or by a slower wet process. To determine which method is permissible, oven-dry a moist part of the material and then examine its dry strength by breaking it up by hand. If it can be easily crushed and the fine material changed to a powder by finger pressure as illustrated on page 42, the dry method

of separation may be used. If the sample has considerable dry strength and the fine material cannot be thoroughly powdered by finger pressure, the wet method of separation is required.

Dry Method

1. Powder about 150 grams of dry material with rubber-covered pestle on clean, smooth surface.

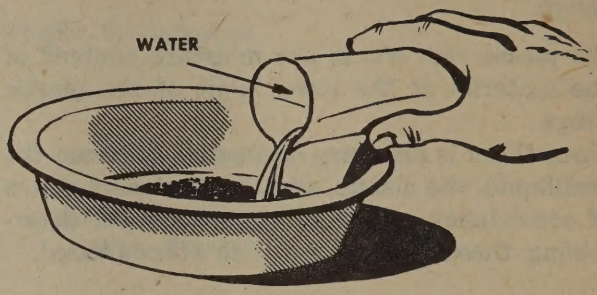
2. Screen powdered sample through the No 40 sieve and discard the material retained on sieve.



3. Mix soil passing No 40 sieve with water until it has the consistency of a very thick, smooth paste. Cover with damp paper or cloth and let stand for not less than 1 hour.

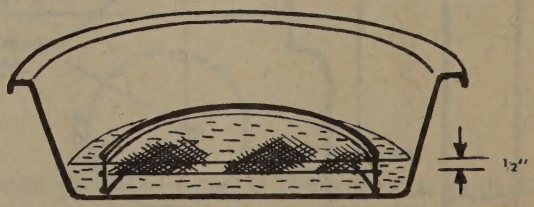
Wet Method

1. Break up the required amount of material with rubber-covered pestle or rolling pin.



2. Transfer sample to saucepan and cover with water. Let soak until all material is disintegrated. This may require 2 to 12 hours.

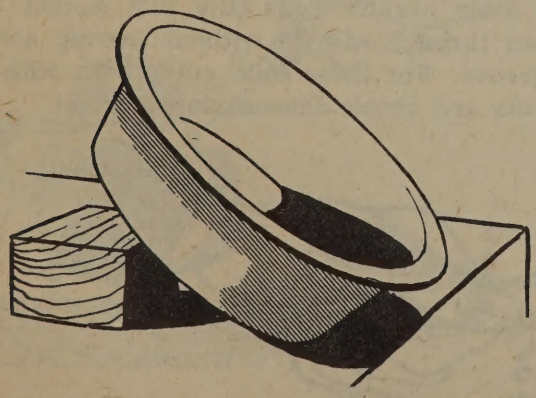
3. Place a No 40 sieve in a saucepan and transfer entire soaked sample into the sieve. Wash any material still adhering to the soaking pan into the sieve by squirting water from the battery filler.



4. Pour clean water into pan containing sieve until level of water is about ½-inch above mesh in sieve.

5. Without lifting sieve, agitate it with one hand. At the same time, stir material with the other hand until all fine material appears to have passed through sieve.

6. Hold sieve slightly above water surface in pan and squirt water from battery filler onto sieve until retained particles and the sieve are clean. Discard material retained in sieve.

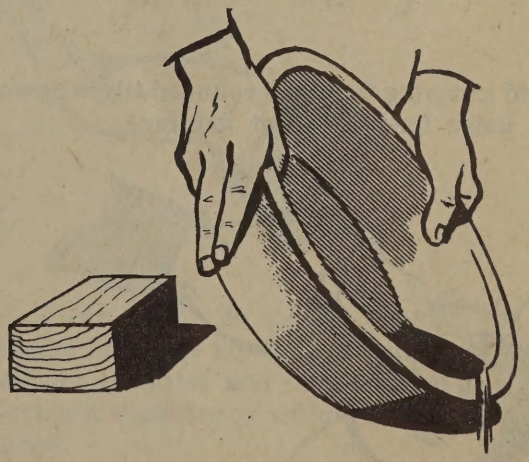


7. Place pan where it will not be disturbed and block it up on one side so water on the other side barely reaches rim of pan. Allow soil to settle for several hours.

NOTE: For most soils, material in suspension will settle out. If there is no indication of this after several hours, one of the following procedures can be used to speed up the process.

If time is available, place pan in hot oven until excess water evaporates; then proceed with step 9.

If there is little time for test, pour a salt solution (½-teaspoonful common table salt dissolved in a cup of water) slowly into pan. This causes suspended material to flocculate. However, it may change test results and should be used only when time is limited.



8. Pour off liquid slowly by gradually increasing tilt of pan until cloudy layer overlying the sediment reaches rim of pan.

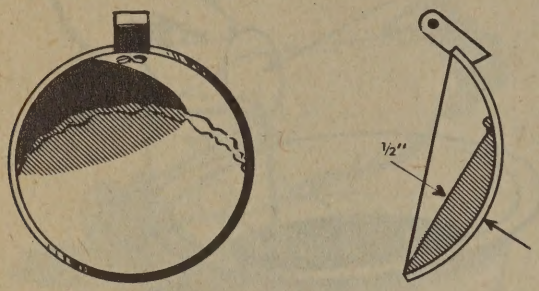
9. Air-dry material to the consistency of a thick, smooth paste and put in small mixing dish.

LIQUID-LIMIT TEST

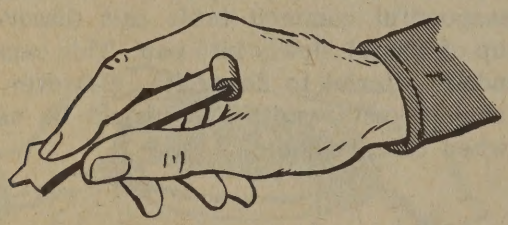
Just before making liquid-limit test, thoroughly mix sample once more with spatula and set aside about 1 heaped teaspoonful of material for the plastic-limit test.

Test Procedure

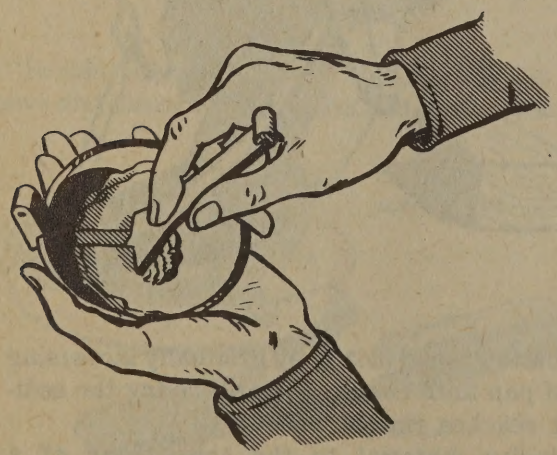
1. Transfer enough material from mixing dish into brass cup of liquid-limit device to fill the cup about one-third full.



2. Hold cup and use spatula to mix and spread material, forming a smooth cake about ½ inch deep in lower half of cup.



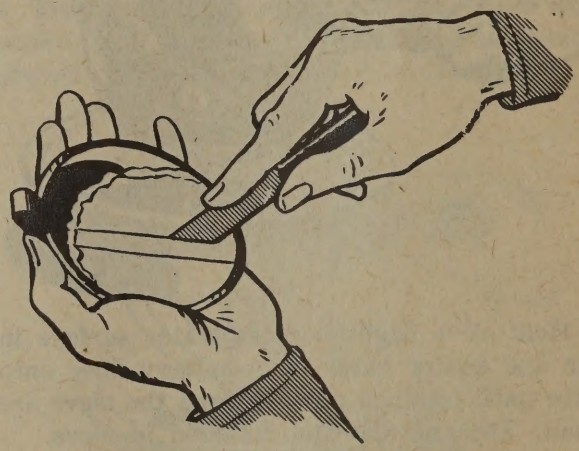
3. Hold grooving tool with rounded edges downward, index finger against flat face.



4. Place point of tool on upper edge of soil cake with tool perpendicular to surface of cup.

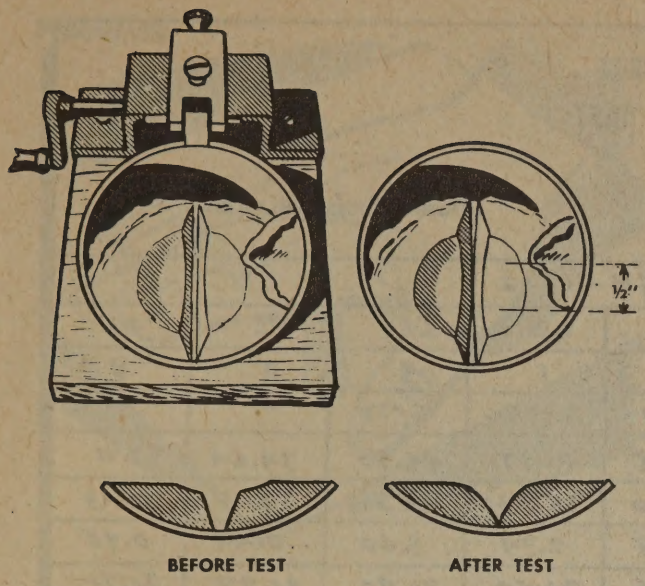
5. Draw tool down through the center of cake along a line extending from the center of the cup handle. At the same time, tilt the tool so it remains perpendicular to the bottom surface.

For clays containing little or no sand, cut groove with one smooth continuous stroke.



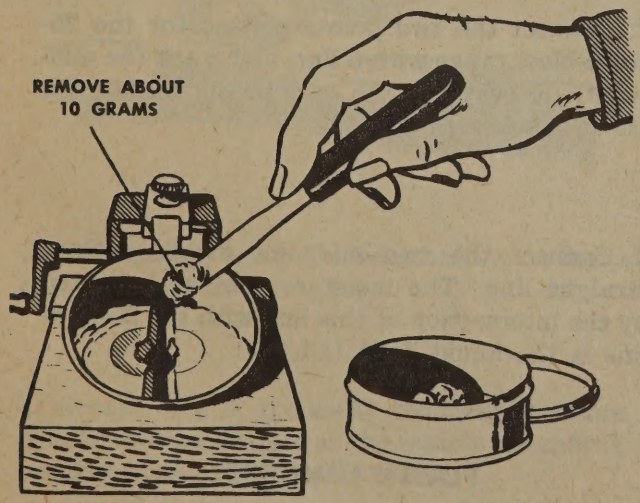
For very sandy clays, silts having little plasticity, and some organic soils, the tool cannot be drawn through sample without tearing sides of groove. For these soils, cut groove with a spatula and check dimensions with tool.

6. Clean grooving tool by wiping thumb over cutting edge before laying it aside. If soil dries on tool, time is lost in cleaning it later.



7. With striking parts of the liquid-limit device clean and dry and height of drop properly adjusted, place cup in device, turn crank at rate of about two blows per second, and count number of blows required to close bottom of groove for a distance of about ½ inch.

NOTE: If groove is not closed ½ inch in 25 to 35 blows, add water and remix or dry sample to a consistency within this range.



8. Remove cup from device, remix and regroove sample, and repeat step 7. If second test gives same number of blows as first or does not differ more than one blow, record both numbers on data sheet.

If difference is more than one blow, repeat test until three consecutive tests give a reasonable consistent sequence of numbers, such as 30-32-30, or 30-28-30 (typical of a humid atmosphere) or 30-32-34 (typical of a dry atmosphere)

9. Remove approximately 10 grams of material from closed portion of groove. Place material in small metal box and cover tightly.
10. Remove cup from device, remix and regroove sample, and repeat steps 7, 8, and 9

11. Place about 20 grams of material from mixing dish into liquid limit cup. Add a slight amount of water and mix to a uniform paste having a consistency within the 10- to 20-blow range.

12. Groove sample and repeat steps 7, 8, 9, and 10.

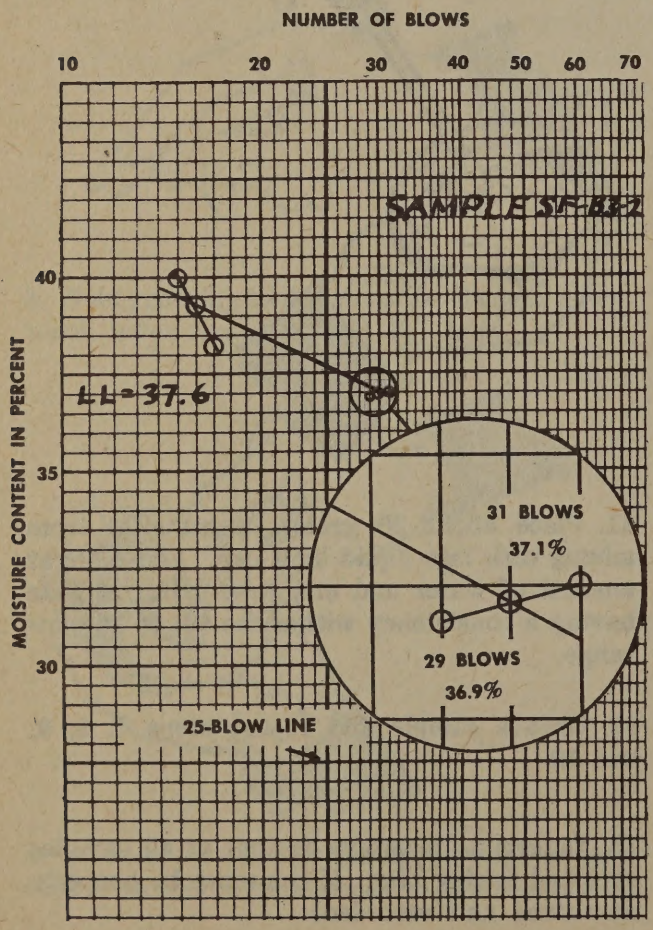
13. Determine moisture content of all samples obtained during test. (Cans must be properly numbered and recorded.)

DATA SHEET
PLASTICITY TEST

Initials SDW Date 19 June 45

Sample No	SF-B3-2					
Type of test	LL	LL	LL	LL	PL	PL
Can No	3	7	1	4	5	8
No of blows	31-29-29	30-31	16-15	16-17	–	–
Wt wet sample + can (gm)	48.65	43.88	40.97	44.96	34.64	37.11
Wt dry sample + can (gm)	43.97	40.60	38.23	41.36	34.15	36.13
Wt water (gm)	4.68	3.28	2.74	3.60	0.49	0.98
Wt can (gm)	31.28	31.76	31.40	31.92	31.88	31.71
Wt dry sample (gm)	12.69	8.84	6.83	9.44	2.27	4.42
Moisture content (%)	36.9	37.1	40.1	38.1	21.6	22.2

Derivation of Liquid Limit



1. Plot relationship between moisture content and number of blows (use last figure in sequence) on semilogarithmic paper as shown.

2. Connect the two points plotted for the 25- to 35-blow range with a line, and mark the midpoint. Repeat for the two points within the 10- to 20-blow range.

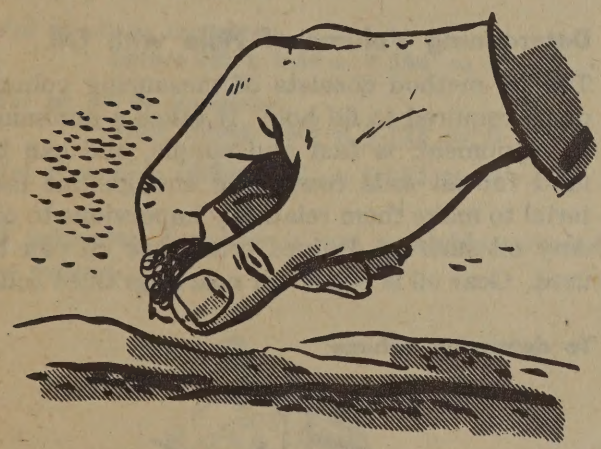
3. Connect the two midpoint marks with a straight line. The moisture content indicated by the intersection of this line with the 25-blow line is the liquid limit (LL).

PLASTIC-LIMIT TEST

The small sample which was set aside at the start of the liquid-limit test is allowed to dry to a consistency such that the material will not stick to the hands, yet can still be rolled into a thread without crumbling.

Procedure

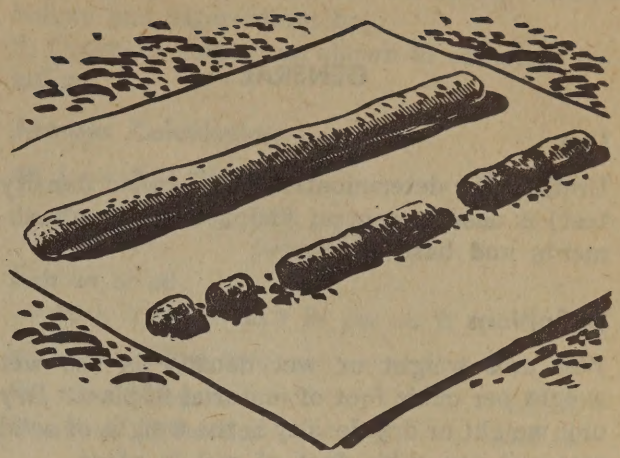
1. Take not more than one-half of this sample and roll with palm of hand on any clean, smooth surface such as a sheet of paper, to form a ⅛-inch thread about 3 inches long.



2. Fold thread and press together into a lump, and then roll it out again.

3. Repeat step 2, gradually reducing moisture content by evaporation as the sample is handled, causing threads to become stiffer.

4. The plastic limit (PL) is reached when the thread crumbles into a number of pieces while being rolled.



NOTE: If any doubt exists as to whether the PL has been reached, lump the pieces together and roll out again.

5. Immediately place the crumbled thread into a small metal box and determine moisture content.

6. Make another PL determination for a check, using material from remaining portion of original sample.

Data Sheet

The same data sheet is used for both the plastic-limit and liquid-limit tests.

PLASTICITY INDEX

The numerical difference between the liquid limit (LL) and the plastic limit (PL) is the plasticity index (PI).

$$PI = LL - PL$$

For example:

$$LL = 38$$
$$PL = 22$$
$$PI = 38 - 22 = 16$$

UNIT-WEIGHT DETERMINATION

GENERAL

Use

Unit-weight determination (also called density test) is used to control compaction of embankments and base courses.

Definitions

Wet unit weight or wet density is the wet weight per cubic foot of material in place. Dry unit weight or dry density is the weight of solid material per cubic foot of soil in place.

VOLUME-OF-HOLE PROCEDURE

Obtaining Sample

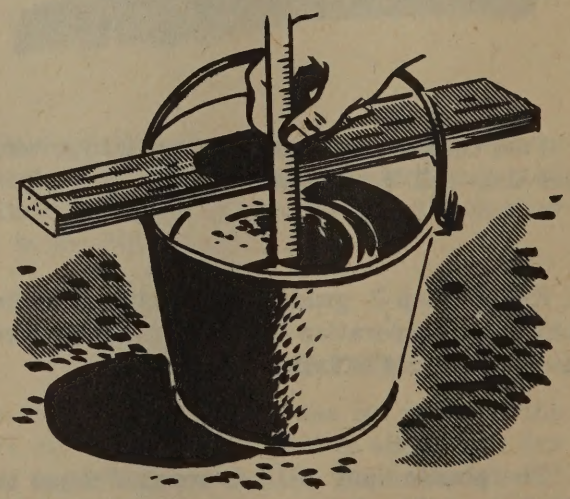
1. Clear all loose material from an area approximately 2 feet in diameter. Level area carefully, and fill in low spots with nearby soil, if necessary. Tamp firmly with board or other flat object.
2. Mark a circle on ground 8 to 10 inches in diameter.
3. Excavate material from circle with auger, spoon, screwdriver, or small pick, and place all material removed in a container. The hole should be about 8 inches deep, but should not extend through more than one type of material.

If moisture content is also to be determined take small separate sample and seal.

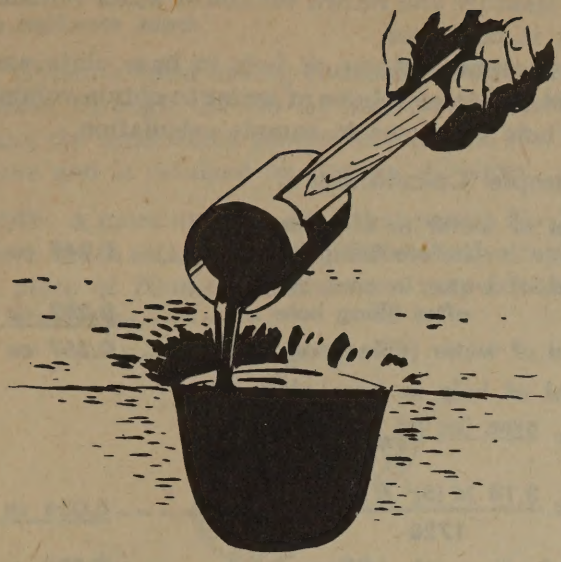
Determining Volume of Hole with Oil

The oil method consists of measuring volume of oil required to fill hole. It takes a minimum of equipment, is fast and simple, and can be used for all soils containing enough fine material to make them relatively impervious to oil. Any oil such as drained crankcase oil can be used. Gear oil is better for coarse-grained soils.

To determine volume:



1. Measure and record volume of oil in calibrated bucket (page 18).



2. Pour oil into hole until it is level with original ground surface.
3. Measure and record volume of oil remaining in container.

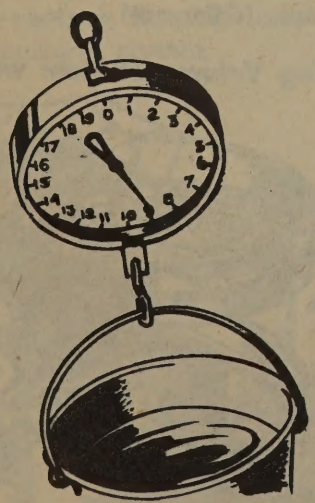
Sample Calculation:

Vol of oil in container before filling hole = 0.356 cu ft

Vol of oil in container after filling hole = 0.123 cu ft

Vol of sample (difference) = 0.233 cu ft

If calibrated container is not available, proceed as follows:



1. Determine weight of oil to be used in pounds per cubic foot by weighing a known volume of oil.

2. Weigh oil and container on spring balance before and after filling hole.
3. Compute volume as shown in sample calculation.

Sample Calculation:

Wt 1 qt oil (1/30 cu ft) ---------- **842 gm**

$$= \frac{842}{454} = 1.855 \text{ lb}$$

Unit wt of oil

= 30 X 1.855 = 55.7 lb per cu ft

Wt before filling hole ---------- **21.2 lb**

Wt after filling hole ---------- **8.2 lb**

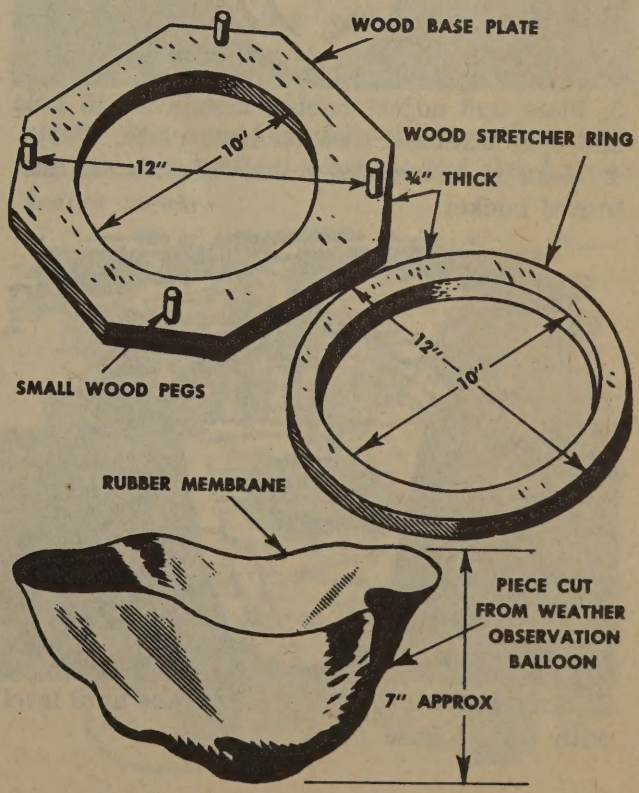
Wt of oil (difference) ---------- **13.0 lb**

$$\text{Vol of hole} = \frac{\text{wt of oil}}{\text{unit wt of oil}}$$

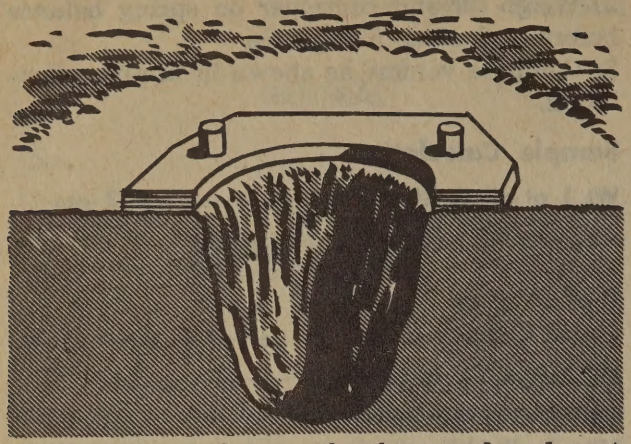
$$= \frac{13.0}{55.7} = 0.233 \text{ cu ft}$$

Determining Volume of Hole with Water

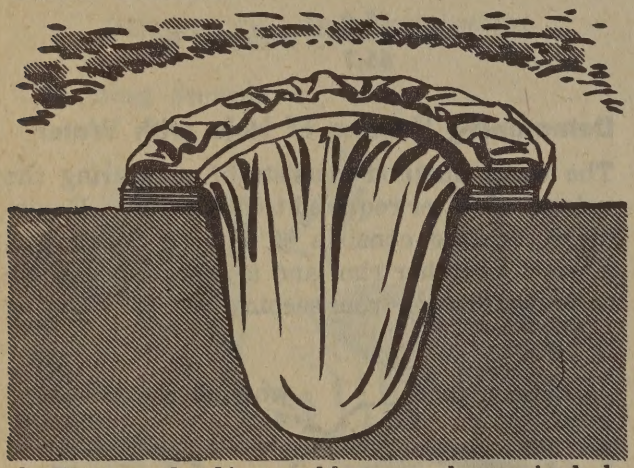
The water method consists of measuring the volume of water required to fill the hole. Equipment required consists of a wood base plate, a wood stretcher rim, and a rubber membrane to prevent water from seeping into surrounding soil.



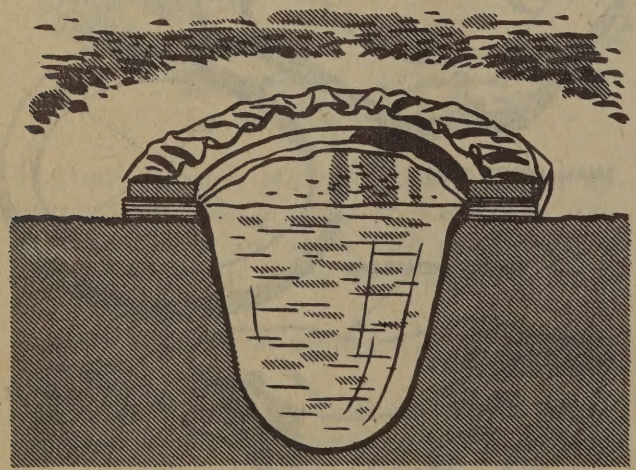
To determine volume by water method:



1. Place base plate on level ground and seat it well.
2. Excavate hole slightly smaller than size of rubber membrane.



3. Place and adjust rubber membrane in hole and seat stretcher rim on base plate.
4. Measure and record volume of water in calibrated bucket.



5. Pour water into rubber membrane until level with top of base plate.
6. Measure and record volume of water remaining in container.
7. Compute volume of hole in base plate and subtract from volume of water to obtain volume of hole as shown in sample calculation.

Sample Calculation:

Vol of water in container before filling hole ..... 0.349 cu ft

Vol of water in container after filling hole ..... 0.082 cu ft

Vol of water (difference) ..... 0.267 cu ft

Vol of hole in base plate

$$= \frac{\text{area (sq in)} \times \text{thickness (in)}}{1728}$$

$$= \frac{3.14 \times (5)^2 \times 0.75}{1728} = \text{.....} 0.034 \text{ cu ft}$$

Vol of sample (difference) = ... 0.233 cu ft

If calibrated container is not available, weigh container with water on spring balance before and after filling hole; then compute volume as shown in sample calculation.

Sample Calculation

Wt before filling hole ..... 27.3 lb

Wt after filling hole ..... 10.6 lb

Wt of water (difference) ..... 16.7 lb

$$\text{Vol of water} = \frac{\text{wt of water}}{62.4}$$

$$= \frac{16.7}{62.4} \text{ .....} 0.267 \text{ cu ft}$$

Vol of hole in base plate ..... 0.034 cu ft

Vol of sample (difference) ..... 0.233 cu ft

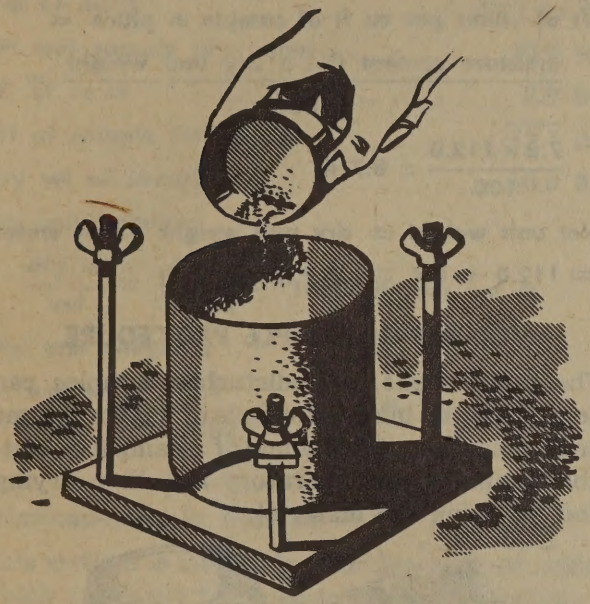
Determining Volume of Hole with Sand

The sand method may be used in any type of soil, but dry calibrated sand must be used.

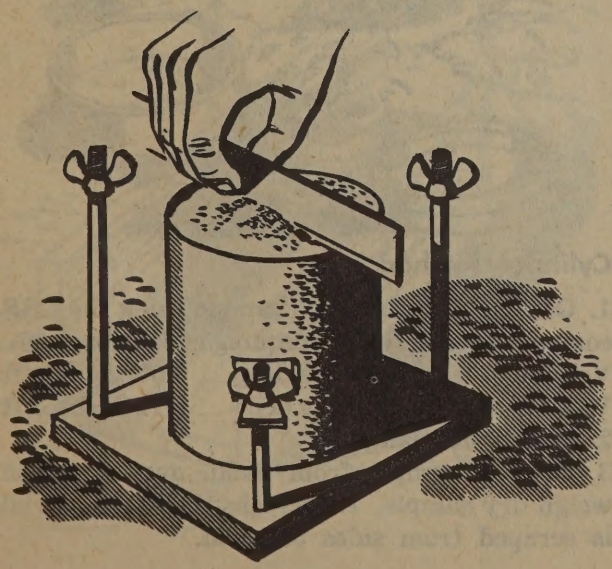
To calibrate sand:

1. Obtain a sand having rounded particles and screen through the No 10 and No 40 sieves. Save the sand which passes through the No 10 sieve and is retained on the No 40 sieve.

NOTE: A more uniform sand that passes No 10 sieve and is retained on No 20 sieve is desirable. A piece of 20-mesh wire screen may be used if available.



2. Thoroughly wash this sand in water and then dry in oven.
3. Pour sand into a compaction mold (1/30-cubic-foot volume) from a height about 4 inches above sand surface, keeping the falling sand in a small uniform stream.



4. Strike off surface with a straightedge, being careful not to jar mold or vibrate sand.
5. Weigh sand contained in mold and compute unit weight as shown in sample calculation. The average of several separate determinations is used.
6. Place sand in airtight container until used. The sand must be perfectly dry when used in field or results will be erratic.

Sample Calculation

Wt of sand in mold = ---- 1418 grams

$$= \frac{1418}{454} = 3.12 \text{ lb}$$

Unit wt of sand =

3.12 x 30 = 93.6 lb per cu ft

To determine volume using calibrated sand:

1. Weigh container with sand on spring balance.
2. Using a funnel or can, pour sand loosely into hole from height about 4 inches above sand surface. Keep falling sand in a small, steady stream, and distribute it over entire area of hole.
3. Strike off surface of sand level with ground, being careful not to compact sand. Return any excess sand to container.
4. Reweigh container with sand.
5. Compute volume as shown in sample calculation.

NOTE: The sand is usually salvaged from hole, but must be sifted, washed, and dried again before re-use.

Sample Calculation

Wt before filling hole ..... 27.4 lb

Wt after filling hole ..... 5.6 lb

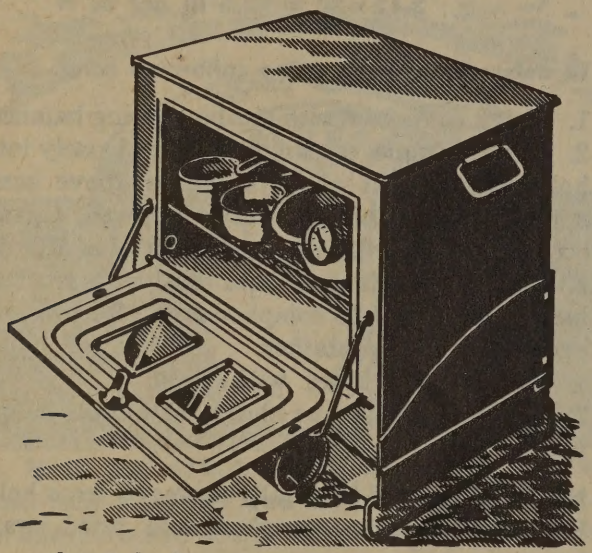
Wt of sand in hole (difference) 21.8 lb

Vol of sample =

$$\frac{\text{wt of sand in hole}}{\text{unit wt of sand}} = \frac{21.8}{93.6} = 0.233 \text{ cu ft}$$

Determining Dry Weight of Soil Sample

The soil excavated from hole is placed in pans and oven-dried (air drying is permissible in dry atmosphere), then weighed on spring balance. If facilities do not permit drying entire sample, weigh the wet sample, determine moisture content of a representative sample (page 41), and compute dry weight as shown below:



Sample Calculation

Wet wt of sample ..... 28.1 lb

Moisture content of sample 7.8%

Dry wt of sample =

$$100 \times \frac{\text{wet wt of sample}}{100 + \%\text{ moisture content}} =$$

$$100 \times \frac{28.1}{100 + 7.8} = 26.1 \text{ lb}$$

Unit-weight Calculation

Dry unit weight is calculated by dividing weight of dry sample by volume of sample in place as previously determined. (See sample calculation.)

Wet unit weight is calculated by computing weight of water contained in 1 cubic foot of sample and then adding to dry unit weight as shown in sample calculation.

Sample Calculation

Wt of dry sample ..... 26.1 lb

Vol of sample in place ..... 0.233 cu ft

$$\text{Dry unit weight} = \frac{\text{wt of dry sample}}{\text{vol of sample in place}} =$$

$$\frac{26.1}{0.233} = 112.0 \text{ lb per cu ft}$$

Moisture content = ... 7.8%

Wt of water per cu ft of sample in place =

$$\frac{\text{moisture content (\%) x dry unit weight}}{100} =$$

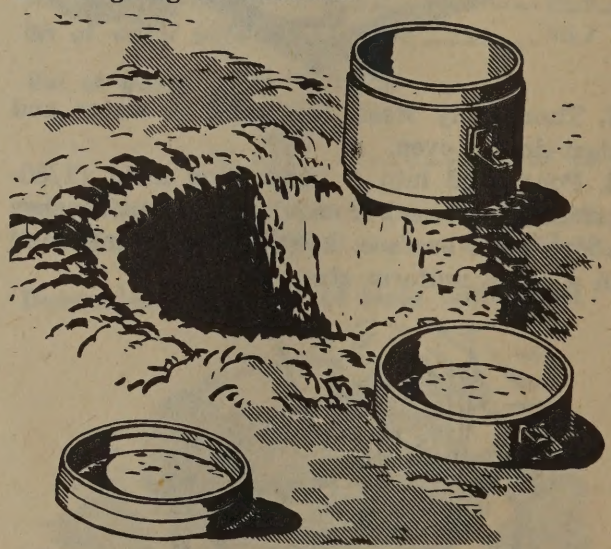
$$\frac{7.8 \times 112.0}{100} = 8.7 \text{ lb}$$

Wet unit weight = dry unit weight + wt water

= 112.0 + 8.7 = 120.7 lb per cu ft

VOLUME-OF-SAMPLE PROCEDURE

The unit weight of undisturbed samples can be obtained by taking a sample of known volume or by measuring the volume of a sample of suitable shape in the laboratory and then drying and weighing the material.



Cylinder Method

1. Obtain an undisturbed sample using the CBR compaction mold with sampling collar (page 28).
Volume of mold 6 inches deep .. 0.0982 cubic ft
Volume of mold 7 inches deep .. 0.1145 cubic ft
2. Weigh wet sample.
3. Remove sample from mold, oven-dry, and weigh dry sample. Be certain that all material is scraped from sides of mold.

NOTE: Drying the entire sample is recommended, but the dry weight of sample can also be computed by determining moisture content of a representative sample.

4. Compute dry weight in pounds per cubic foot as shown in sample calculation. Other suitable containers, such as empty shell cases, can be used after measuring their volumes.

Sample Calculation

Vol of mold ..... 0.0982 cu ft

Wt wet sample plus mold ..... 20.0 lb

Wt of mold ..... 7.9 lb

Wt of sample (difference) ..... 12.1 lb

Dry wt of sample ..... 10.0 lb

Dry unit weight =

$$\frac{\text{dry wt}}{\text{vol}} = \frac{10.0}{0.0982} = 101.8 \text{ lb per cut ft}$$

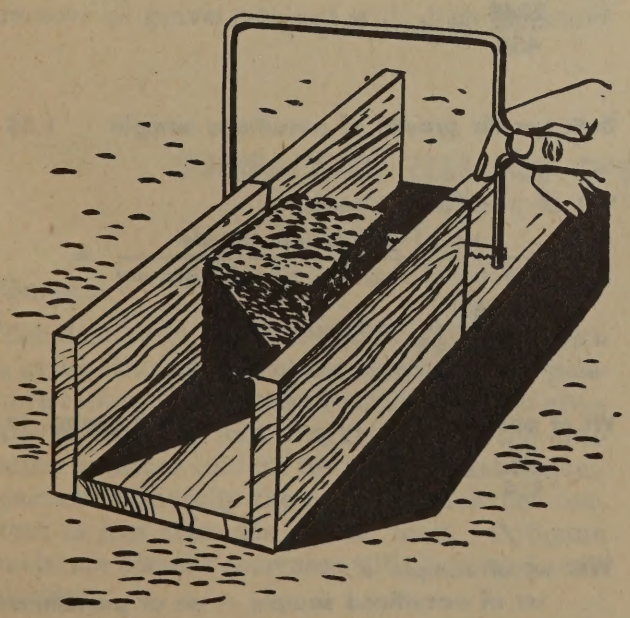
Wet unit weight =

$$\frac{\text{wet wt}}{\text{vol}} = \frac{12.1}{0.0982} = 123.2 \text{ lb per cu ft}$$

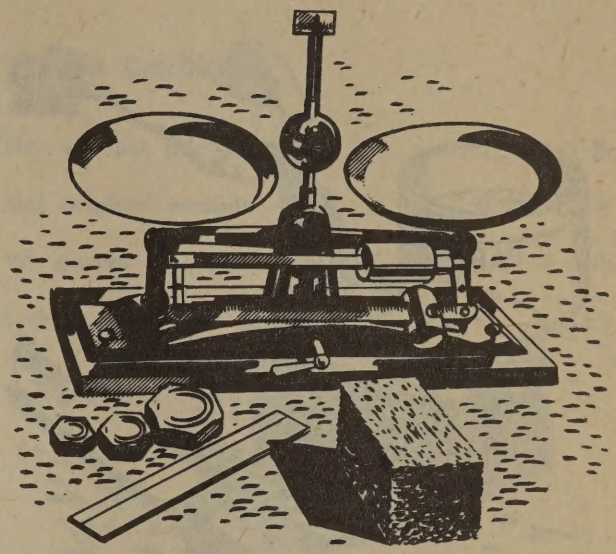
Trimmed-sample Method

This method is used only with fine-grained soils which are easily trimmed to any desired shape.

1. Trim an undisturbed sample (see Soil Sampling), to a block-like shape, using miter box and wire saw.



2. Measure and record dimensions and compute volume of sample. Weigh wet sample if wet unit weight or moisture content is desired.
3. Oven-dry sample and reweigh.
4. Compute unit weight as shown in sample calculation.



Sample Calculation

Width of sample ..... 4.0 in

Breadth of sample ..... 4.0 in

Depth of sample ..... 6.0 in

$$\text{Vol of sample} = \frac{\text{width x breadth x depth}}{1728} =$$

$$\frac{4.0 \times 4.0 \times 6.0}{1728} = 0.0555 \text{ cu ft}$$

Wet wt of sample = 2,497 grams, or

$$\frac{2497}{454} = 5.50 \text{ lb}$$

Dry wt of sample = 2270 grams, or

$$\frac{2270}{454} = 5.00 \text{ lb}$$

$$\text{Dry unit wt} = \frac{\text{dry wt}}{\text{vol}} =$$

$$\frac{5.00}{0.0555} = 90.1 \text{ lb per cu ft}$$

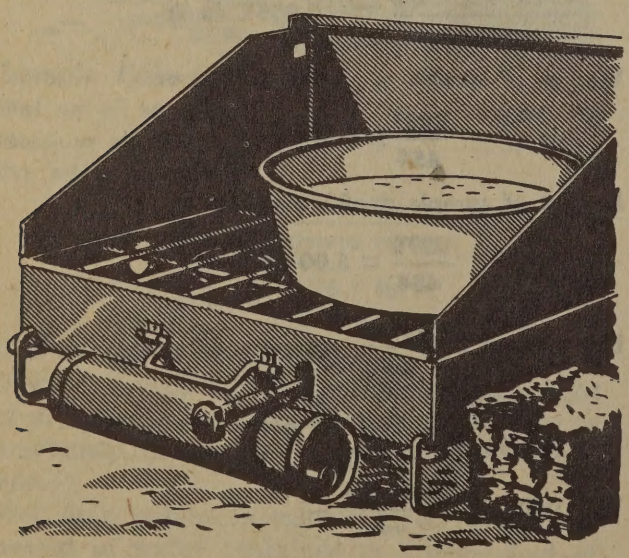
$$\text{Wet unit wt} = \frac{\text{wet wt}}{\text{vol}} =$$

$$\frac{5.50}{0.0555} = 99.1 \text{ lb per cu ft}$$

Chunk-sample Method

The chunk-sample method takes longer than the above methods, but must be used when the unit weight of an irregular chunk sample is desired and trimming to regular dimensions is not practicable.

1. Trim off surface irregularities and coat sample with melted paraffin by repeated dipping or painting. Carefully eliminate any air pockets trapped in paraffin.
2. Determine bulk specific gravity of paraffined sample by method shown on page 40.



3. Remove all paraffin from sample and place paraffin, including any adhering soil, into saucepan partially filled with water. Boil until all paraffin is melted.

4. When water cools, dirt-free paraffin hardens on surface. Remove and weigh paraffin.
5. Oven-dry sample, including material retained in pan after paraffin is removed, and weigh.
6. Compute dry weight in pounds per cubic foot as shown in sample calculation.

Sample Calculation

Wt of paraffined sample = 2048 grams, or

$$\frac{2048}{454} = 4.51 \text{ lb}$$

Bulk specific gravity of paraffined sample 1.55

Vol of paraffined sample =

$$\frac{\text{wt of paraffined sample}}{\text{unit wt of water} \times \text{specific gravity}} =$$

$$\frac{4.51}{62.4 \times 1.55} = 0.0466 \text{ cu ft}$$

Wt of paraffin ---------- 83 grams, or

$$\frac{83}{454} = 0.18 \text{ lb}$$

Wet wt of sample =

wt of paraffined sample − wt of paraffin =

4.51 − 0.18 = 4.33 lb

$$\text{Vol of paraffin} = \frac{\text{wt of paraffin}}{\text{unit wt of paraffin}} = \frac{0.18}{54.3} = 0.0033 \text{ cu ft}$$

Vol of sample =
vol of paraffined sample − vol of paraffin =
0.0466 − 0.0033 = 0.0433 cu ft

Wt of dry sample _____ 3.95 lb

$$\text{Dry unit weight} = \frac{\text{wt of dry sample}}{\text{vol of sample}} = \frac{3.95}{0.0433} = 91.2 \text{ lb per cu ft}$$

$$\text{Wet unit weight} = \frac{\text{wet wt of sample}}{\text{vol of sample}} = \frac{4.33}{0.0433} = 100.0 \text{ lb per cu ft}$$

FIELD CONTROL OF UNIT WEIGHT

To control compaction of gravelly soils, the dry unit weight of the material passing a ¼-inch sieve must be obtained so it can be compared with dry unit weight obtained by laboratory compaction.

Procedure

1. After volume of hole has been determined, remove all gravel retained on ¼-inch sieve and wipe dry with cloth.
2. Weigh to nearest 0.1 pound.
3. Determine specific gravity of gravel (see page 38).
4. Calculate dry unit weight of material passing ¼-inch sieve as shown in sample calculation.

Sample Calculation

Dry wt fine portion _____ 22.0 lb

Vol original sample _____ 0.233 cu ft

Wt gravel _____ 4.1 lb

Specific gravity of gravel _____ 2.65

$$\text{Vol gravel} = \frac{\text{wt gravel}}{62.4 \times \text{specific gravity}} = \frac{4.1}{62.4 \times 2.65} = 0.025 \text{ cu ft}$$

Vol fine portion =
vol original sample − vol gravel =
0.233 − 0.025 = 0.208 cu ft

$$\text{Dry unit wt of fine portion} = \frac{\text{dry wt fine portion}}{\text{vol fine portion}} = \frac{22.0}{0.208} = 105.8 \text{ lb per cu ft}$$

COMPACTION TEST FOR OPTIMUM MOISTURE CONTENT

General

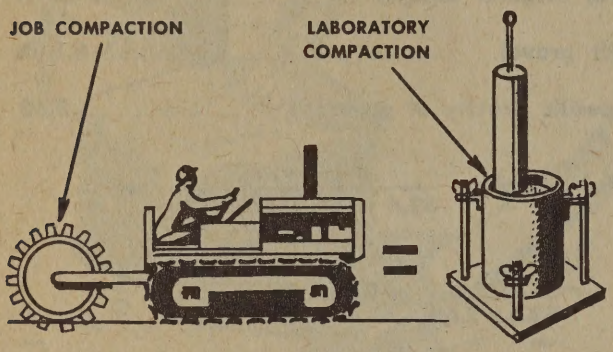
The density to which a soil is compacted with a given compaction method varies with its moisture content. The moisture content which gives the highest dry unit weight is called the optimum moisture content for that method of compaction. Generally the optimum moisture content is less than the plastic limit. Optimum moisture content decreases with increased compaction.

The laboratory compaction method described below has been adopted by the Corps of Engineers, since it generally produces about the same density as is obtained on the job with heavy construction equipment. This method is known as the Modified American Association of State Highway Officials (Modified AASHO) method.

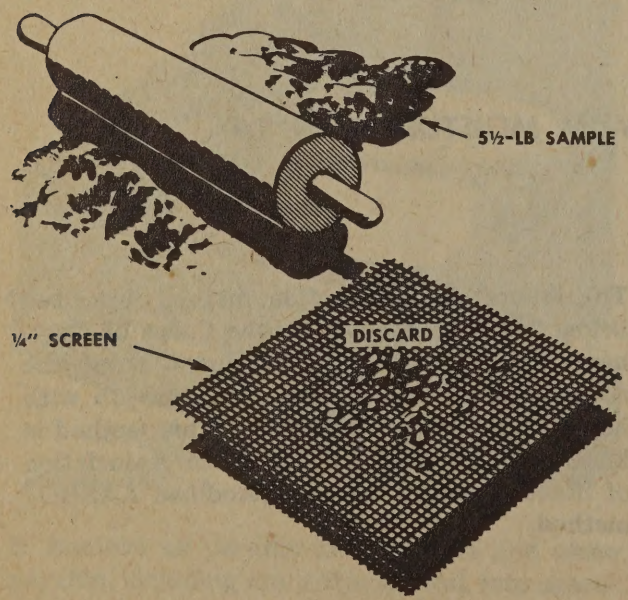
Apparatus Required

Torsion balance	Stove
Triple-beam balance	Screen, ¼-inch
Metal boxes	Spatula
Compaction mold	Rolling pin (page 17)
Compaction tamper	Steel straightedge
Oven	

Preparation of Sample

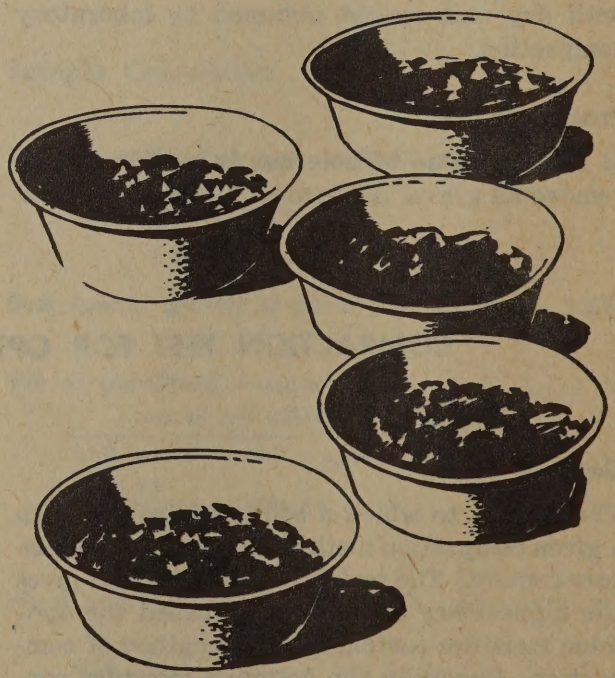


1. Air-dry a representative sample containing from 2 to 2½ kg (4½ to 5½ lb) of dry material smaller than ¼ inch.
2. Break up lumps of fine material by rolling on flat surface.
3. Screen through ¼-inch sieve and discard retained portion.

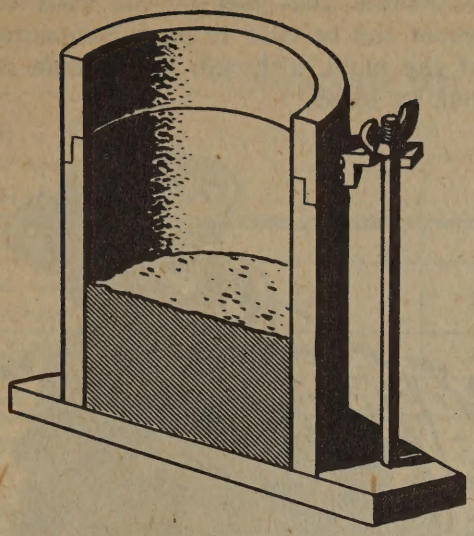


Test Procedure

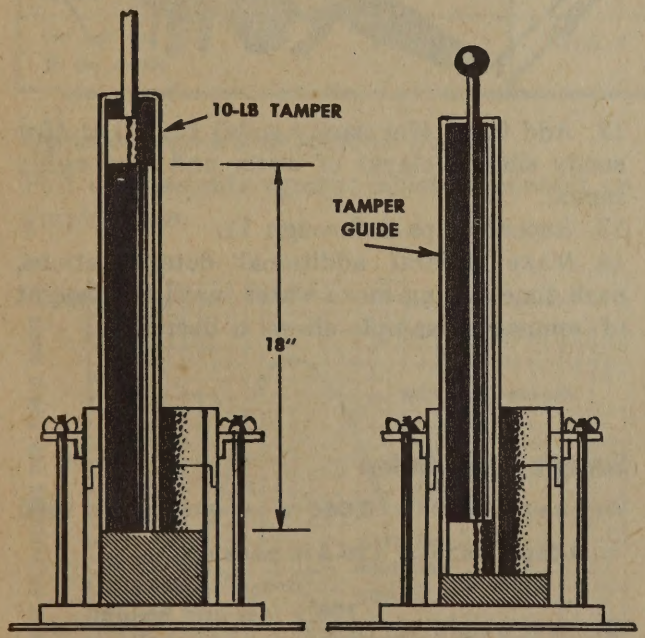
1. Mix sample thoroughly with enough water to form a damp mix that crumbles when released after being squeezed in the hand. Do not get this initial mix too wet.
2. Divide the damp mixture into five approximately equal portions.



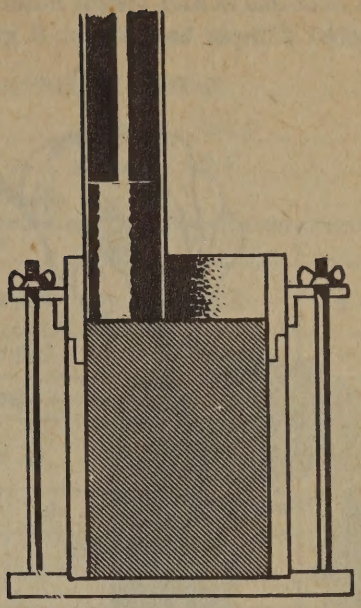
3. Weigh compaction mold on torsion balance to nearest 5 grams; then attach base plate and collar and place on firm foundation.



4. Put one portion of damp mix in compaction mold and level surface by hand.
5. Place compaction tamper with guide on material in mold. Lift tamper handle until tamper reaches top of guide, then release handle, allowing tamper to drop on sample.

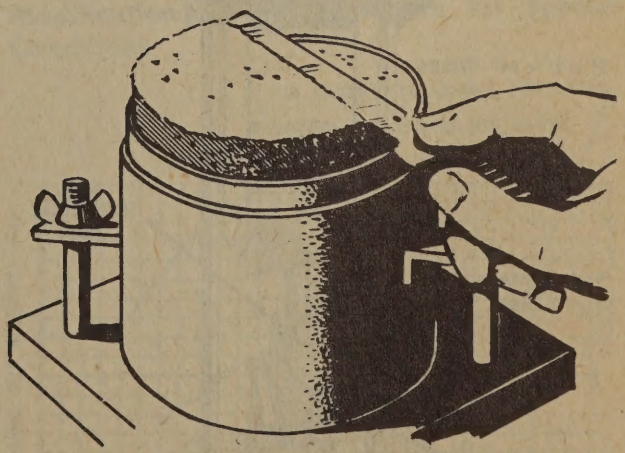


6. Change position of guide and again drop tamper. Repeat process, systematically covering entire surface of sample until tamper is dropped 25 times.



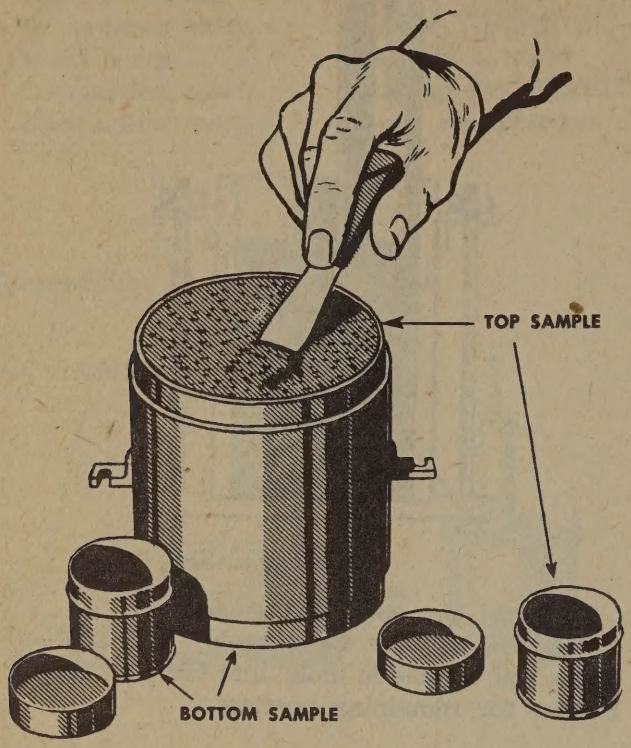
7. Remove tamper from mold, put another portion of sample in mold, and tamp as above. Repeat for remaining portions.

NOTE: Each compacted layer should be about 1 inch deep, and the entire compacted sample should extend at least ½ inch up into the extension collar. The weight of sample required for this purpose is determined by trial and will vary with different soils.

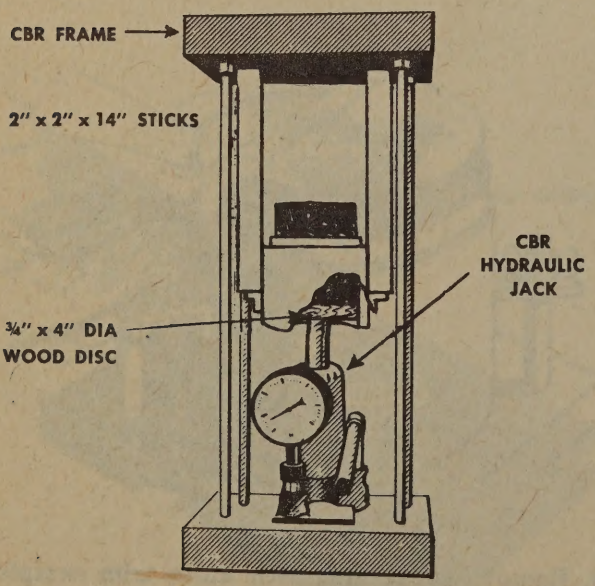


8. Remove collar and with knife trim sample down to rim of compaction mold. Check final leveling with straightedge.

9. Remove base plate and weigh mold containing compacted sample to nearest 5 grams.



10. Take moisture-content samples (10 to 25 grams each) from top and bottom of mold. (The average value is used in final calculations.)
11. Remove compacted soil from mold, repulverize with rolling pin, and place in pan.



NOTE: Frame and jack of the CBR testing equipment can be used to push compacted soil out of the mold, although the sample can be dug out by hand.

12. Add 60 cc (for sandy soils) to 120 cc (for sandy silts or clays) of water and thoroughly remix.
13. Repeat steps 3 through 11.
14. Make several additional determinations, each time adding more water, until the weight of compacted sample shows a decrease.

Sample Calculation

Wet unit weight = 0.066 x wt wet sample (gm)

= 0.066 x 1825 = 120.5 lb per cu ft

$$\text{Dry unit weight} = \frac{100 \times \text{wet unit weight}}{100 + \text{moisture content (\%)}}$$

$$= \frac{100 \times 120.5}{100 + 7.4} = 112.2 \text{ lb per cu ft}$$

DATA SHEET

Sample No SF-P4-1

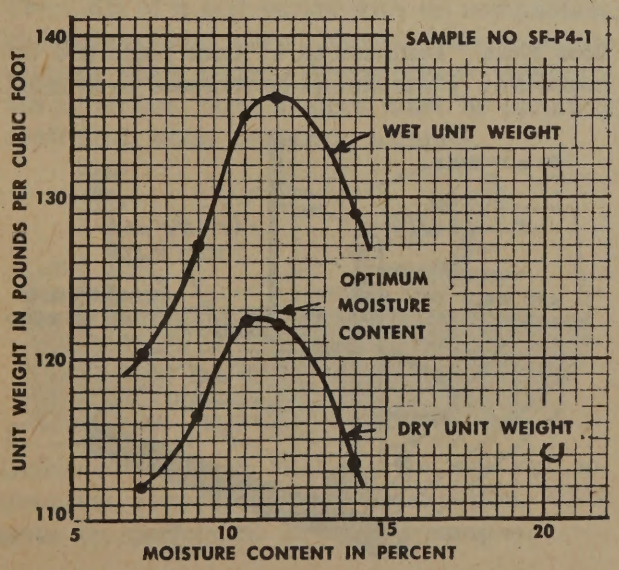
COMPACTION TEST FOR OPTIMUM MOISTURE CONTENT

Initials SDW
Date 19 JUNE 1945
No of layers 5
No of blows per layer 25
Weight of tamper 10 LB
Height of drop 18"

Test No	1		2		3		4		5	
Wt wet sample + mold (gm)	3,860		3,955		4,080		4,095		3,990	
Wt mold (gm)	2,035		2,035		2,035		2,035		2,035	
Wt wet sample (gm)	1,825		1,920		2,045		2,060		1,955	
Wet unit wt (lb per cu ft)	120.5		126.7		135.0		136.0		129.0	
Can No	3	7	1	4	5	8	2	10	6	9
Wt wet sample + can (gm)	42.24	45.34	40.36	42.92	38.96	41.11	50.83	47.61	53.88	49.50
Wt dry sample + can (gm)	41.52	44.36	39.63	41.98	38.32	40.19	48.90	45.96	51.10	47.31
Wt water (gm)	0.72	0.98	0.73	0.94	0.64	0.92	1.93	1.65	2.78	2.19
Wt can (gm)	31.28	31.76	31.40	31.92	31.88	31.71	32.08	31.64	30.96	31.66
Wt dry sample (gm)	10.24	12.60	8.23	10.06	6.44	8.48	16.82	14.32	20.14	15.65
Moisture content (%)	7.0	7.8	8.9	9.3	9.9	10.9	11.5	11.5	13.8	14.0
Average moisture content (%)	7.4		9.1		10.4		11.5		13.9	
Dry unit wt (lb per cu ft)	112.0		116.1		122.3		122.0		113.3	

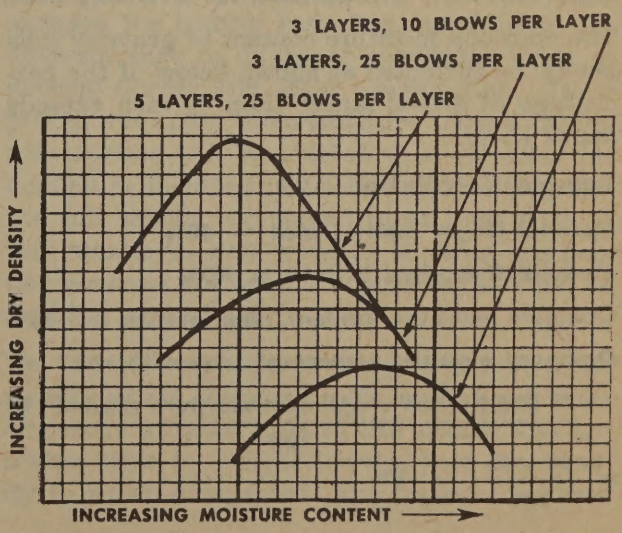
Optimum-Moisture-Content Curve

Plot unit weights against moisture content on graph paper.

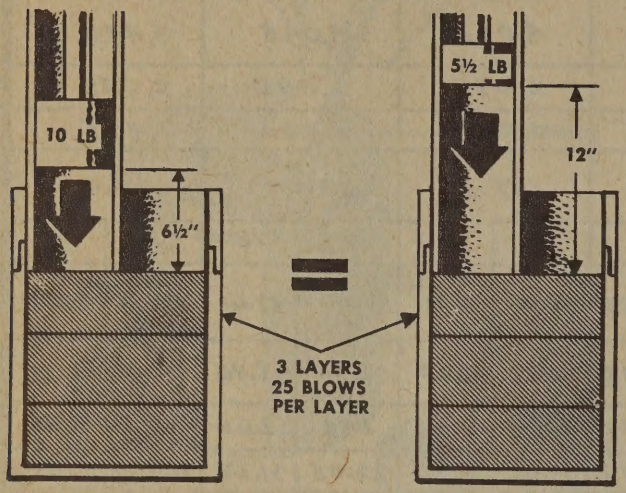


The optimum moisture content is the moisture content at the peak of the dry unit-weight curve.

Modification of Test Procedure for Special Conditions


3 LAYERS, 10 BLOWS PER LAYER
3 LAYERS, 25 BLOWS PER LAYER
5 LAYERS, 25 BLOWS PER LAYER
INCREASING DRY DENSITY
INCREASING MOISTURE CONTENT

The above test procedure may not produce the same densities as those produced on the job by construction equipment. For example, airborne equipment may produce lower densities and heavy construction equipment, higher densities. In this case, modify the laboratory procedure by varying the number of layers, the height of drop, and numbers of blows per layer to produce an equivalent density.



The standard Proctor test is generally used for laboratory compaction of cement-stabilized bases. The mold is filled in 3 layers with 25 blows per layer, using a 5½-pound tamper with a 12-inch drop. To use the set equipment, a 6½-inch drop with the 10-pound tamper gives equivalent compaction. If the soil being tested is a uniform fine sand, the tamper may cause upheaval when dropped instead of compaction. If this occurs, first tamp with several light blows to establish initial stability before proceeding with test.

Optimum Moisture Content for Gravelly Soils

The optimum moisture content of gravelly soils should be corrected as shown below, if the percentage of gravel larger than ¼ inch exceeds about 25%.

Sample Calculation

Material larger than ¼ inch = 40%

Material finer than ¼ inch = 60%

Optimum moisture content, fine portion = 15%

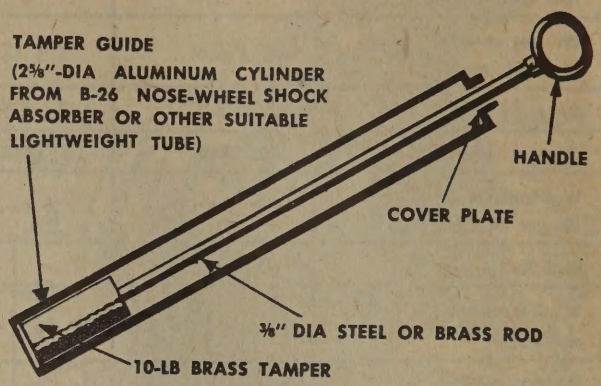
Optimum moisture content of total soil =

$$= \frac{\text{\% fine portion x optimum moisture content (\%)}}{100} = \frac{60 \times 15}{100} = 9\%$$

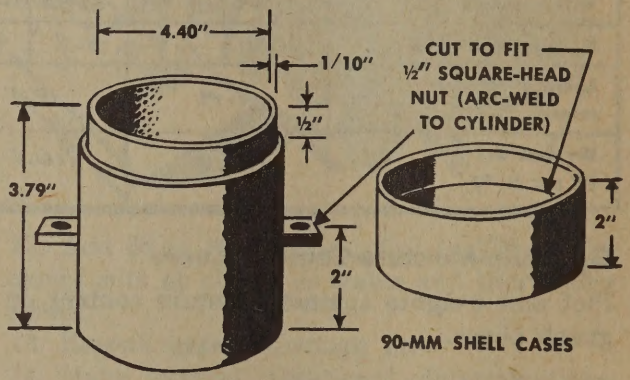
IMPROVISED COMPACTION EQUIPMENT

Tamper and Guide. Any available material can be used, provided the following dimensions and weights are used.

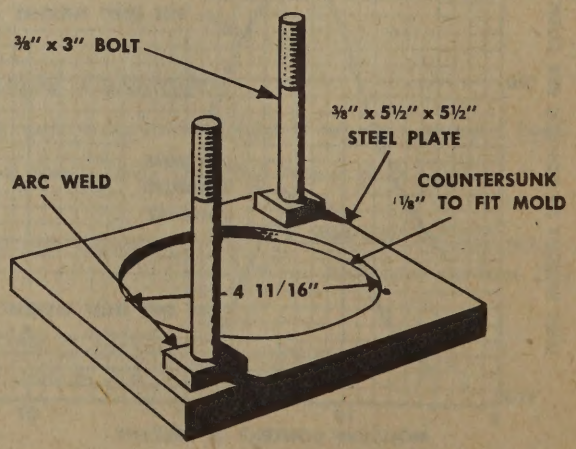
Diameter of tamper = 2 in
Height of drop = 18 in
Weight of tamper = 10 lb


TAMPER GUIDE
(2⅜"-DIA ALUMINUM CYLINDER FROM B-26 NOSE-WHEEL SHOCK ABSORBER OR OTHER SUITABLE LIGHTWEIGHT TUBE)
HANDLE
COVER PLATE
⅜" DIA STEEL OR BRASS ROD
10-LB BRASS TAMPER

Compaction Mold and Collar. Diameter and height of mold should be about the same. Volume should be exactly 1/30 cubic foot.



Base Plate. Dimensions of base plate are unimportant. Plate should be recessed to fit mold.

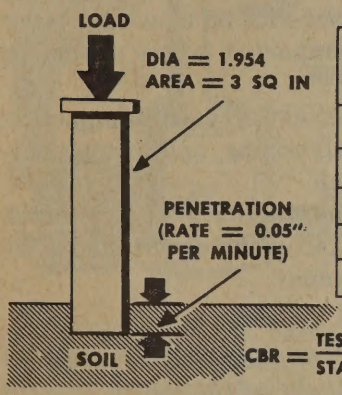


CALIFORNIA BEARING RATIO TEST

GENERAL

Definition

The California bearing ratio (CBR) is a measure of the shearing resistance of a soil under carefully controlled density and moisture conditions and is used with empirical curves for designing flexible pavements. It is expressed as a percentage of the unit load required to force a piston into the soil divided by the unit load required to force the same piston the same depth into a standard sample of crushed stone.



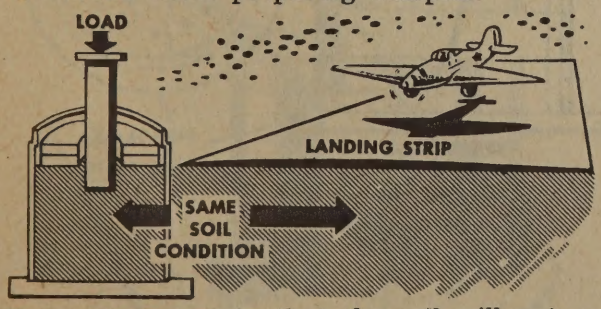
STANDARD VALUES

PENETRATION (IN)	UNIT LOAD (PSI)
0.1	1000
0.2	1500
0.3	1900
0.4	2300
0.5	2600

Unit-load values for various depths of penetration into the standard sample are standardized. The CBR used in design is the 0.1- or 0.2-inch penetration value, whichever is greater. For most soils, the 0.1-inch penetration value is the greater.

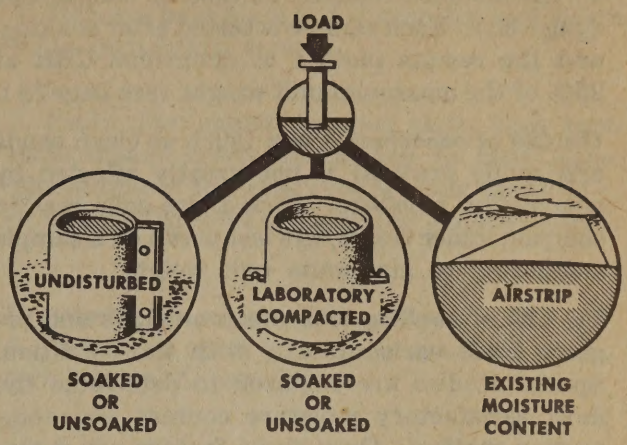
Test Conditions

The CBR of a soil varies with its compaction, moisture content when compacted, and moisture content when tested. Therefore, to duplicate job condition, these factors must be carefully controlled when preparing samples.



Unless it is certain that the soil will not accumulate moisture after construction, CBR tests are performed on soaked samples.

Types of Tests



CBR tests can be made in place on the job, using improvised equipment, or in the laboratory on either undisturbed or laboratory-compacted samples. In-place tests are made only on the soil at its existing moisture content but laboratory tests can be made on either soaked or unsoaked samples. Whenever possible, the test is made on undisturbed soil. For design purposes it is necessary to test laboratory-compacted samples which may not duplicate the density and moisture conditions obtained by job compaction. Therefore, in-place tests or tests on undisturbed job-compacted samples must be made during construction. If results do not agree with preliminary data used for design, either the design must be modified or the job-compaction procedure changed to produce the required CBR.

Preparation of Samples

Procedures to prepare laboratory-compacted samples for testing have been established for different soils to duplicate conditions likely to develop during and after construction. These procedures apply when moisture content during construction will be controlled to optimum for maximum modified AASHO unit weight, and the soil will be compacted to at least 95% of this maximum unit weight. If other compaction controls are used, the procedures must be modified accordingly.

The CBR of low-plasticity, nonswelling soils (such as silty sands, inorganic silts, and clayey silts) is greatly affected in both the soaked and unsoaked state by compaction moisture and density to which compacted. For these soils, three

samples are compacted to various densities at the optimum moisture content predetermined by the modified AASHO method of compaction (page 65). Each sample is tested after soaking, and the results plotted to determine CBR at 95% of the maximum unit weight (see page 78).

The CBR of noncohesive soils (such as clean sands and sandy gravels) is not greatly affected by compaction moisture. Since these soils readily compact under traffic, the test is run on a sample compacted to maximum unit weight.

The CBR of swelling soils (such as clays and organic silts) varies greatly with soil condition. Special studies are required to determine the most satisfactory moisture content and compaction method. Once these factors are determined, the test is run on a sample which is similarly compacted.

TEST ON LABORATORY-COMPACTED SAMPLES

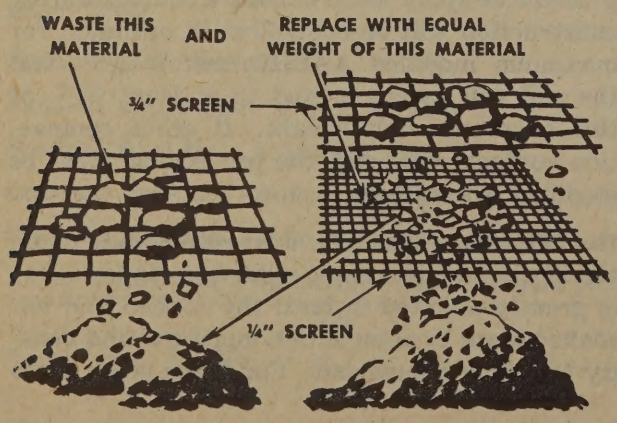
Apparatus Required

CBR equipment
Dial extensometer
Bucket
Compaction tamper
Stove
Oven
Pans
Spring balance
Triple-beam balance
Steel straightedge
Metal boxes
Mixing tools
Rolling pin
Butcher knife
Stop watch

Preparation of Sample

As previously described, the method of preparing the sample depends on the type of material being tested.

To prepare low-plasticity, nonswelling soils:



1. Pulverize about 100 pounds of material with rolling pin, shake through a ¾-inch screen, and throw away material which is retained. Replace wasted material with an equal weight of similar material which passes a ¾-inch screen, but is retained on a ¼-inch screen.

2. Determine optimum moisture content of this material using the modified AASHO method (page 65), with the following exceptions:

a. Use ¾-inch maximum-size material instead of ¼-inch.

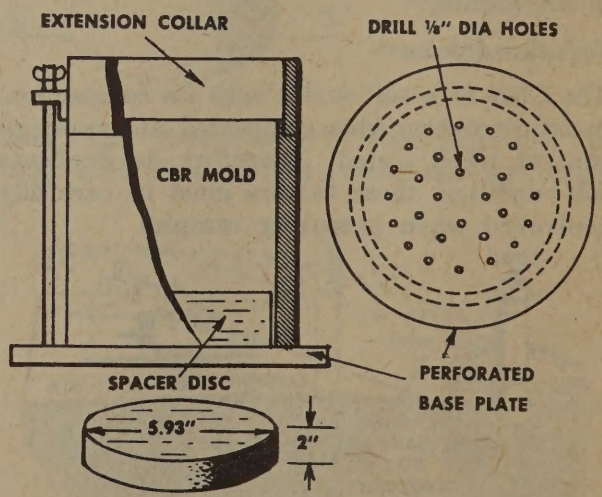
b. Use the CBR compaction mold instead of the 1/30-cubic foot mold.

c. Compact material with 55 blows per layer instead of 25. The compacted layers should be 1 inch thick.

d. Use fresh material for each compaction sample instead of pulverizing and recompacting the same material.

e. To determine optimum moisture content accurately, compact four samples within 2% of optimum (plus or minus).

3. Mix remaining material (about 25 pounds) with enough water to bring moisture content to the optimum as determined in step 2. The moisture content of material must be within 0.5% of the optimum. Cover material with a damp cloth to prevent loss of moisture before compaction.

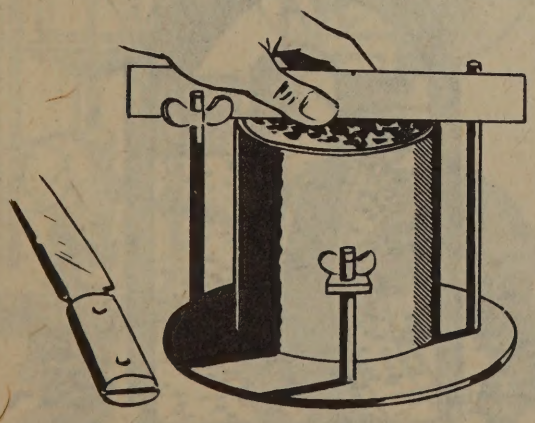


4. Weigh three CBR molds and clamp molds and extension collars to base plates. Insert spacer disc over base plate in each mold.

NOTE: If spacer disc is not provided with equipment, make a disc 2 inches thick and 5.93 inches in diameter of metal or hardwood. (Wood should be soaked in hot paraffin to make waterproof.) Also, if base plate is not perforated, drill 28 1/8-inch holes through plate.

5. Compact three samples in molds taking moisture-content samples (20 to 50 grams each) from top and bottom layers of each mold before compaction. Compact one sample with 55 blows per layer, the second with 25 blows per layer, and the third with 10 blows per layer. Top layer of material should extend at least 1 inch into extension collar, and each compacted layer should be about 1 inch deep.

NOTE: If moisture content of the three compacted samples varies from the optimum by more than 0.5%, the test must be rerun.



6. Remove collar of each mold and with knife trim sample down to rim of mold. Check with straightedge.

7. Remove base plate and spacer disc and weigh mold containing sample.

8. Place filter paper on base plate, then turn mold upside down and attach to base plate. The sample is now ready for soaking (page 74), or testing (page 74), if soaking is not required.

To prepare noncohesive soils:

1. Determine optimum moisture content of material (step 2, page 72).

NOTE: Rigid control of optimum moisture content for noncohesive soils is unnecessary. Three tests are generally sufficient.

2. Compact one sample at optimum moisture content (step 5, above) using 55 blows per layer. Then weigh sample and proceed with steps 6, 7, and 8 above.

To prepare swelling soils:

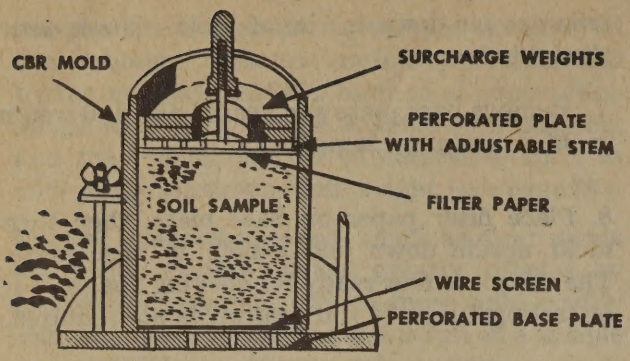
1. Determine the most satisfactory moisture content and compacted unit weight. The values used are those which result in the least swell when sample is soaked.

2. Mix sample with enough water to produce desired moisture content (step 1).

3. Compact sample in mold as described in step 5 above, except the number of blows used is the number required to produce the desired unit weight (step 1 above).

4. Weigh sample and proceed with steps 6, 7, and 8 above.

The above procedures are generally necessary for preparing all samples. However, after an engineer becomes familiar with the soils and probable variations in CBR test results for a given area, it may be possible to reduce the number of samples and to simplify the procedures.

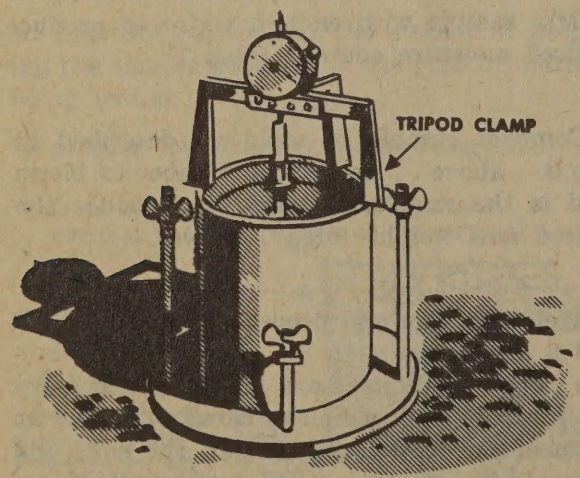


Soaking Sample and Measuring Swell

To duplicate field conditions, the sample is soaked under a **surcharge weight** which is equivalent to the weight produced by the soil, base, or pavement which will overlie that material in the completed structure. One 5-pound lead weight used in the laboratory as a surcharge weight, represents 3 inches of overlying material. To determine required number of surcharge weights, estimate total thickness of overlying material and divide by 3. However, the total surcharge weight must not be less than 10 pounds (two lead weights). If the estimated surcharge weight varies by more than 10 pounds from the surcharge weight which would be used in final design, the test should be repeated using the corrected surcharge weight.

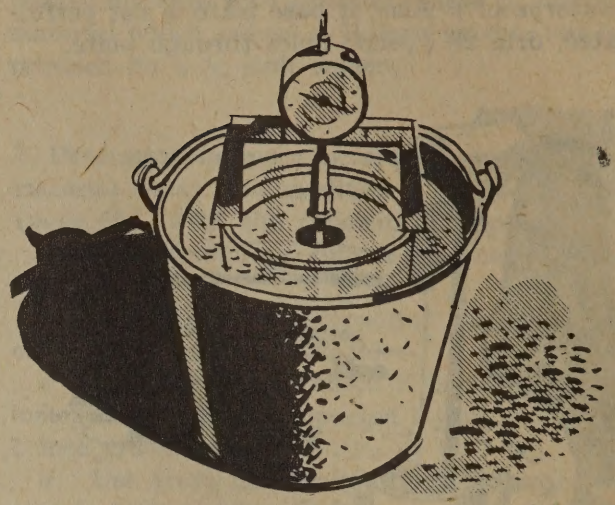
To soak the sample:

1. Place wire screen or filter paper on top of sample. Then place perforated plate with adjustable stem on filter paper. Next put required number of surcharge weights on plate.



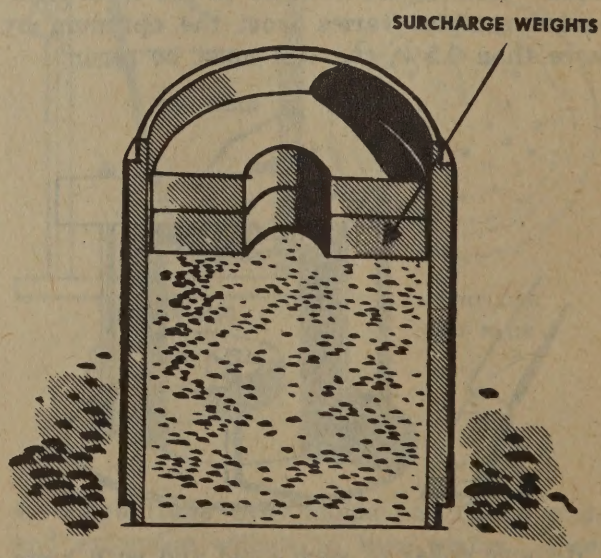
2. Place tripod clamp with dial extensometer on rim of mold and adjust stem of perforated plate. Record reading on dial. Take off tripod.

NOTE: Mark location of tripod legs on mold so additional readings can be taken from same position.



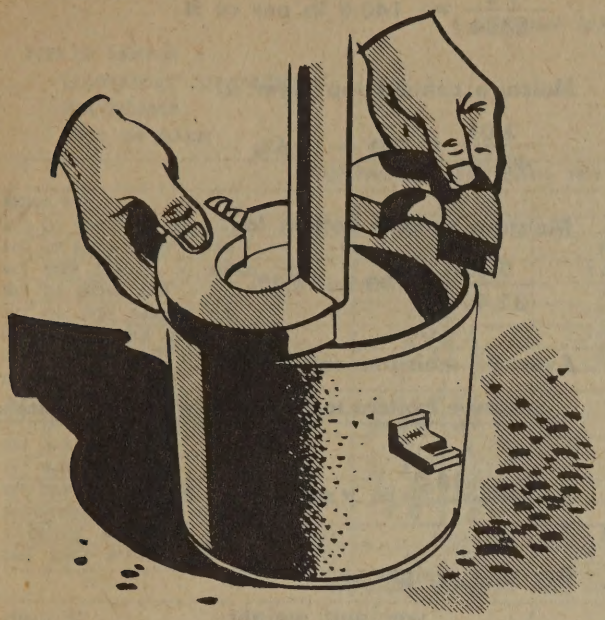
3. Immerse sample in bucket of water and let it soak for 4 days, or until it is thoroughly saturated and does not expand further. Place tripod clamp on sample each day and record dial reading and time of reading.
4. After 4 days, remove mold from water, pour excess water from surface, and let it drain in vertical position for about 15 minutes.
5. Remove lead weights, perforated plate, and filter paper. Sample is ready for testing.

CBR Test Procedure (Penetration Test)

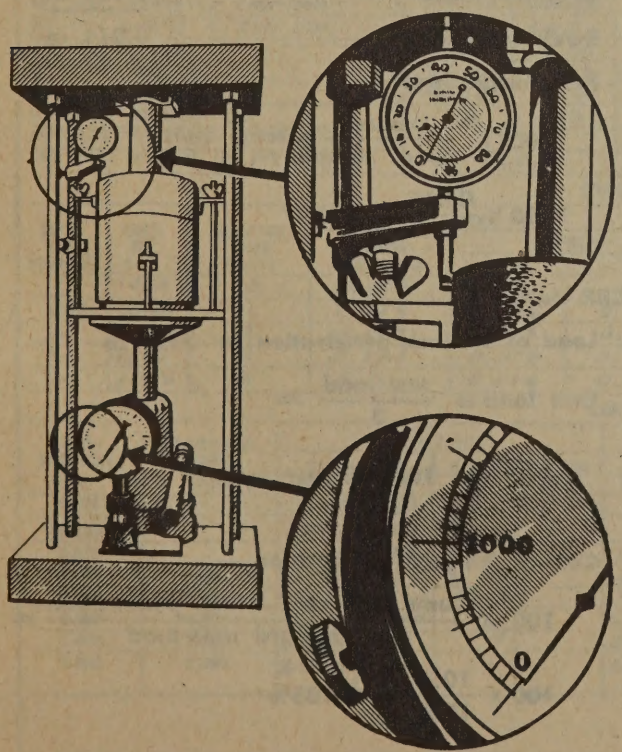


1. Place surcharge weights on sample equal to

weight of surface which will overlie the material. (See Soaking Sample and Measuring Swell, page 74 .)



NOTE: For very soft samples having a CBR of 3% or less, only one 5-pound weight should be added before seating the piston (step 2). Additional weights can then be added as required by cutting the weights in half and inserting each half from opposite sides.

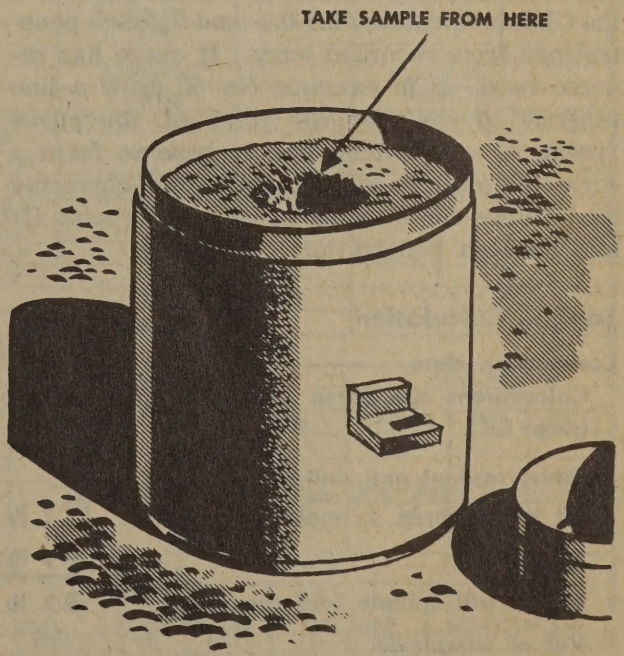


2. Place mold on thrust bearing in loading frame and adjust so piston is centered on sample. Raise jack until piston is seated with a 10-pound load. Since this load is too small to be recorded on pressure gage, it can be estimated by slightly rotating the piston by hand as jack is raised. Set dial gage on hydraulic jack to read zero.

3. Adjust extensometer so stem bears on rim of mold. Set dial face to zero reading.

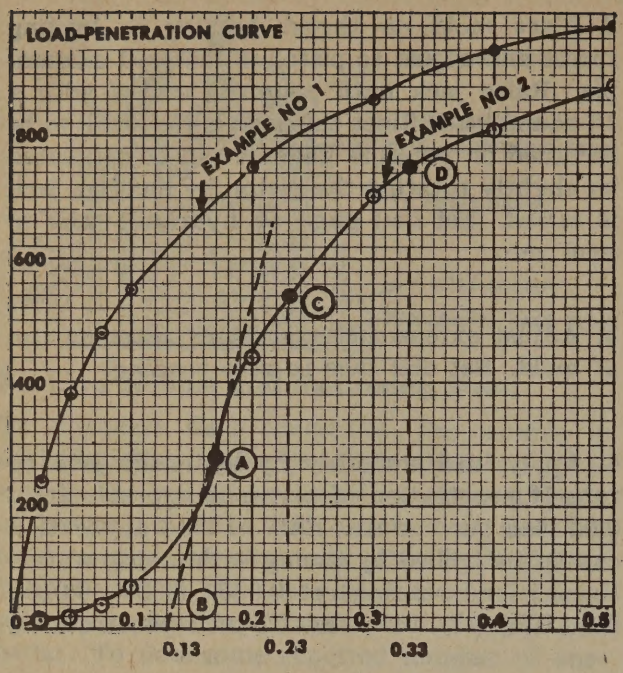
4. Apply load smoothly by hydraulic jack so rate of penetration of piston is approximately 0.05 inch per minute. Rate of load application can be controlled by timing with a stop watch. Record load readings at 0.025-, 0.050-, 0.075-, 0.1-, 0.2-, 0.3-, 0.4-, and 0.5-inch penetrations.

5. Release jack, take mold from loading frame, and remove surcharge weights and base plate.



6. Take a small sample (20 to 50 grams) from top inch of mold for moisture content.

NOTE: To remove sample from mold, see improvised equipment (page 68).



PENETRATION IN INCHES

7. Plot a load-penetration curve on cross-section paper. If curve is uniform as in example No 1, the CBR is calculated for 0.1- and 0.2-inch penetrations from recorded loads. If curve has reverse bend, as in example No 2, draw a line tangent to the steepest point of the curve (point A) and extend line to base to form a corrected zero (point B). Then read corrected load values for 0.1-inch penetration (point C) and 0.2-inch penetration (point D).

Sample Calculation

Compaction data

Calculations are same as for compaction test (page 68).

Moisture-content and unit-weight data

Wt wet sample + mold _____ 17.1 lb

Wt of mold _____ 7.9 lb

Wt of wet sample (difference) _____ 9.2 lb

Vol of sample =

$$\frac{\text{area} \times (\text{ht of mold} - \text{ht of spacer disc})}{1728} =$$

$$\frac{(3.14)(3)^2 \times (6.00 - 2.00)}{1728} =$$

$$\frac{28.26 \times 4}{1728} = 0.0654 \text{ cu ft}$$

$$\text{Wet unit weight} = \frac{\text{wt of wet sample}}{\text{vol of sample}} =$$

$$\frac{9.2}{.0654} = 140.6 \text{ lb per cu ft}$$

Moisture content top layer =

$$\frac{3.05}{40.10} \times 100 = 7.6\%$$

Moisture content bottom layer =

$$\frac{2.66}{32.40} \times 100 = 8.2\%$$

Average moisture content =

$$\frac{\text{moisture content top} + \text{moisture content bottom}}{2} =$$

$$\frac{7.6 + 8.2}{2} = 7.9\%$$

Dry unit weight =

$$\frac{\text{wet unit weight}}{100 + \text{average moisture content}} \times 100 =$$

$$\frac{140.6}{100 + 7.9} \times 100 = 130.3 \text{ lb per cu ft}$$

Swell data

Reading after 4 days _____ 0.121 in

Original reading _____ 0.105 in

Swell (difference) _____ 0.016 in

Percentage swell =

$$100 \times \frac{\text{swell}}{\text{ht of sample}} =$$

$$100 \times \frac{0.016}{4} = 0.4\%$$

CBR data

Load at 0.1-inch penetration = 3150 lb

$$\text{Unit load} = \frac{\text{test load}}{3} =$$

$$\frac{3150}{3} = 1050 \text{ lb per sq in}$$

CBR at 0.1-inch penetration =

$$100 \times \frac{\text{unit load at 0.1-inch penetration}}{\text{standard unit load}} =$$

$$100 \times \frac{1050}{1000} = 105\%$$

DATA SHEET

SAMPLE NO SF-P1-2

CALIFORNIA BEARING RATIO TEST

TYPE OF SAMPLE:
- LABORATORY COMPACTED ✓
- UNDISTURBED
- FIELD (IN PLACE)

DATE 19 JUNE 1945
INITIALS SDW
SURCHARGE Two 5-LB weights
TYPE OF SOIL Clayey sand

COMPACTION-TEST DATA FOR OPTIMUM MOISTURE CONTENT

MOLD NO	1	1	1	1	1
NO OF LAYERS	5	5	5	5	5
NO OF BLOWS PER LAYER	55	55	55	55	55
WT WET SAMPLE + MOLD (LB)	21.0	21.3	21.7	21.6	21.4
WT OF MOLD (LB)	7.9	7.9	7.9	7.9	7.9
WT OF WET SAMPLE (LB)	13.1	13.4	13.8	13.7	13.5
VOL OF SAMPLE (CU FT)	.0982	.0982	.0982	.0982	.0982
WET UNIT WEIGHT (LB PER CU FT)	133.4	136.5	140.5	139.5	137.5
CAN NO	5 / 7				
WT WET SAMPLE + CAN (GM)	63.69 / 66.07				
WT DRY SAMPLE + CAN (GM)	61.88 / 63.98	(To be filled in from test data)			
WT WATER (GM)	1.81 / 2.09				
WT CAN (GM)	31.28 / 31.76				
WT DRY SAMPLE (GM)	30.60 / 32.22				
MOISTURE CONTENT (%)	5.9 / 6.5				
AVERAGE MOISTURE CONTENT (%)	6.2	6.9	8.0	9.0	10.0
DRY UNIT WEIGHT (LB PER CU FT)	125.6	127.7	130.1	128.0	125.0

MOISTURE CONTENT AND UNIT WEIGHT OF TEST SAMPLES

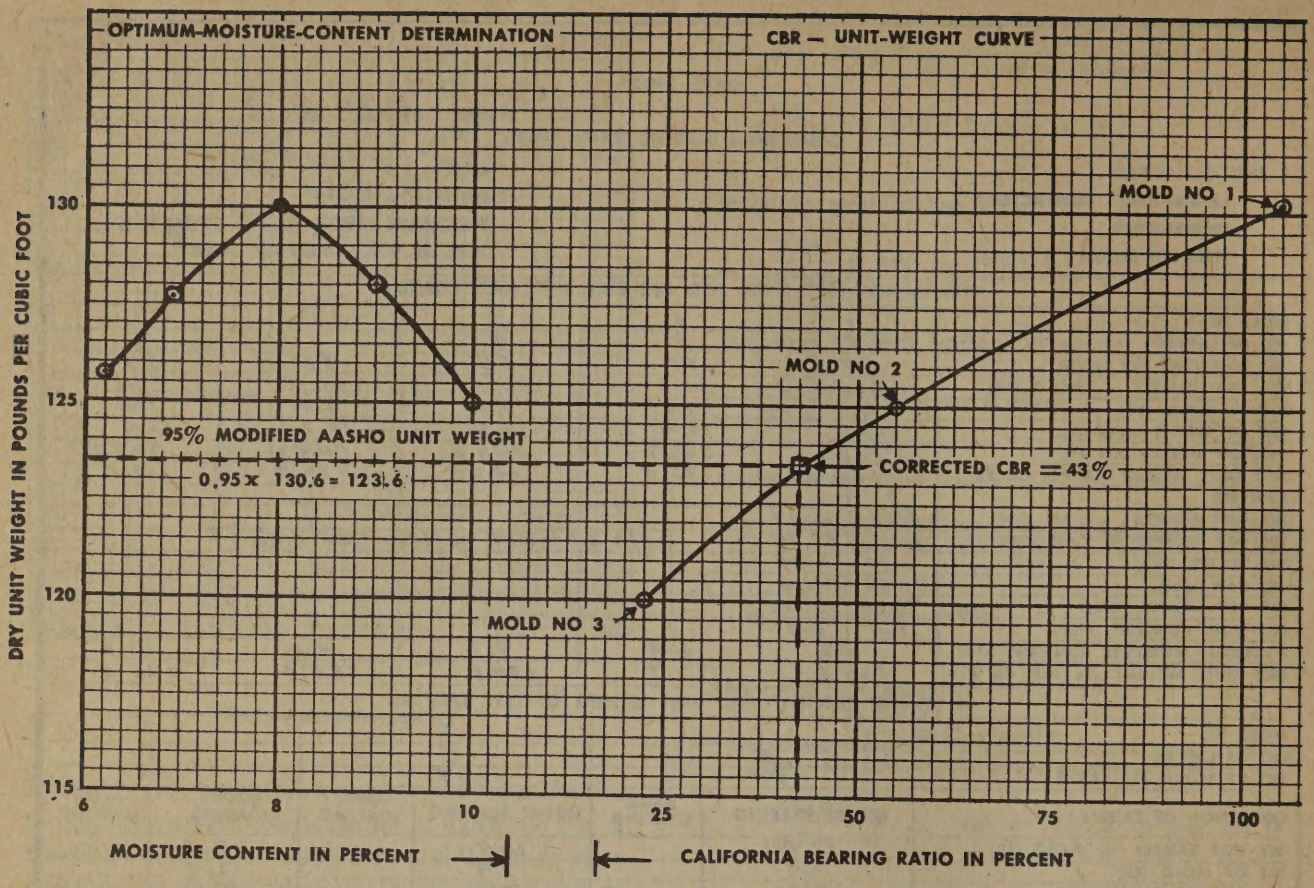
MOLD NO	1			2			3		
NO OF LAYERS	5			5			5		
NO OF BLOWS PER LAYER	55			25			10		
CONDITION OF SAMPLE	BEFORE SOAKING		AFTER SOAKING	BEFORE SOAKING		AFTER SOAKING	BEFORE SOAKING		AFTER SOAKING
WT WET SAMPLE + MOLD (LB)	17.1			16.7			16.4		
WT OF MOLD (LB)	7.9			7.9			7.9		
WT OF WET SAMPLE (LB)	9.2			8.8			8.5		
VOL OF SAMPLE (CU FT)	0.0654			0.0654			0.0654		
WET UNIT WEIGHT (LB PER CU FT)	140.6			134.6			130.0		
MOISTURE CONTENT SAMPLE FROM	BOTTOM	TOP	TOP INCH	BOTTOM	TOP	TOP INCH	BOTTOM	TOP	TOP INCH
CAN NO	1	4	5						
WT WET SAMPLE + CAN (GM)	74.55	66.48	71.15						
WT DRY SAMPLE + CAN (GM)	71.50	64.32	67.48	(To be filled in from test data)					
WT WATER (GM)	3.05	2.66	3.67						
WT CAN (GM)	31.40	31.92	31.88						
WT DRY SAMPLE (GM)	40.10	32.40	35.60						
MOISTURE CONTENT (%)	7.6	8.2	10.3						
AVERAGE MOISTURE CONTENT (%)	7.9			7.7			8.3		
DRY UNIT WEIGHT (LB PER CU FT)	130.3			125.0			120.0		

SWELL DATA

DAY OF MONTH	TIME OF DAY	ELAPSED TIME (DAY)	MOLD NO 1 GAGE READING	MOLD NO 1 SWELL (IN)	MOLD NO 1 SWELL (%)	MOLD NO 2 GAGE READING	MOLD NO 2 SWELL (IN)	MOLD NO 2 SWELL (%)	MOLD NO 3 GAGE READING	MOLD NO 3 SWELL (IN)	MOLD NO 3 SWELL (%)
19	1000	0	0.105								
20	1030	1	0.113	0.008	0.2	(To be filled in from test data)					
21	0930	2	0.117	0.012	0.3						
22	1100	3	0.121	0.016	0.4						
23	1000	4	0.121	0.016	0.4						

CBR DATA

PENETRATION (IN)	STANDARD LOAD (PSI)	MOLD NO 1 TEST LOAD (LB)	MOLD NO 1 TEST LOAD (PSI)	MOLD NO 1 CORRECTED CBR (PSI)	MOLD NO 1 CORRECTED CBR (%)	MOLD NO 2 TEST LOAD (LB)	MOLD NO 2 TEST LOAD (PSI)	MOLD NO 2 CORRECTED CBR (PSI)	MOLD NO 2 CORRECTED CBR (%)	MOLD NO 3 TEST LOAD (LB)	MOLD NO 3 TEST LOAD (PSI)	MOLD NO 3 CORRECTED CBR (PSI)	MOLD NO 3 CORRECTED CBR (%)
0.025		1,350	450	No		30	10			240	80	No	
0.050		2,010	670	Correction		60	20			450	150	Correction	
0.075		2,610	870	Necessary		120	40			600	200	Necessary	
0.100	1,000	3,150	1050			210	70	540	54	690	230		23
0.200	1,500	4,560	1520			1320	440	740	49	910	320		21
0.300	1,900	5,610	1870			2100	700			1020	340		
0.400	2,300	6000+				2430	810			1050	350		
0.500	2,600	6000+				2640	880			1050	350		



Corrected CBR at 95% Modified AASHO Density

To determine the corrected CBR of low-plasticity nonswelling soils (page 71), it is first necessary to obtain the CBR of three samples compacted to different unit weights (page 73). The relationship between unit weight and CBR for each of the three samples is plotted on cross-section paper. Then draw a horizontal line at a unit weight equal to 95% of maximum unit weight obtained for the sample compacted with 55 blows per layer. The intersection of this line with the CBR-unit weight curve determines the corrected CBR at 95% modified AASHO density.

TEST ON UNDISTURBED SAMPLES

Apparatus Required

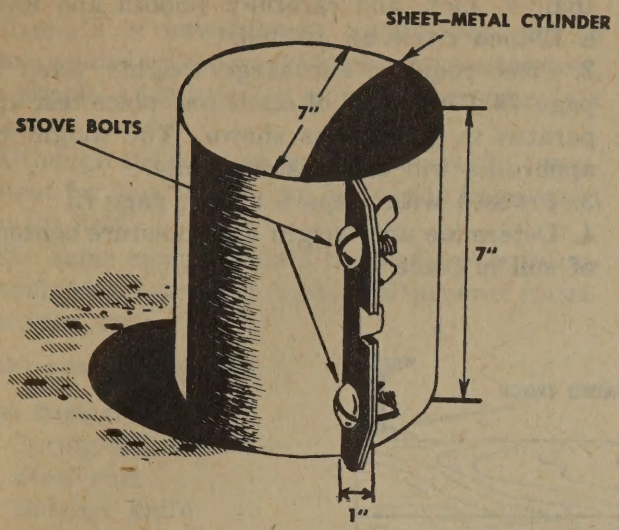
CBR equipment	Stop watch
Spring balance	Dial extensometer
Wood discs (page 18)	Split jacket

Preparation of Sample

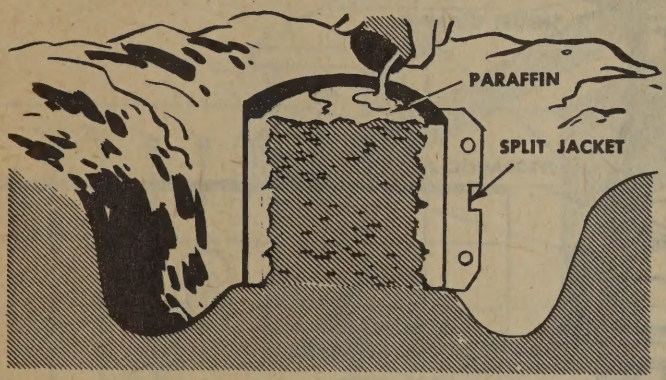
For soft soils, take a cylinder sample in the CBR compaction mold (pages 28 to 29). The CBR mold can only be used for soft materials that will completely fill the mold. Results will not be accurate if there is any space between sample and mold walls. Take moisture-content samples from area adjacent to hole. Determine dry unit weight of material (page 62) and proceed as follows:

1. Remove protective cover from one end of sample and trim or fill in with sand to produce a surface flush with end of mold.
2. Place wire screen or filter paper over trimmed end of sample and attach perforated base plate.
3. Invert the mold, remove protective cover from other end, and smooth the surface. Attach the extension collar to mold and the sample is ready for soaking.

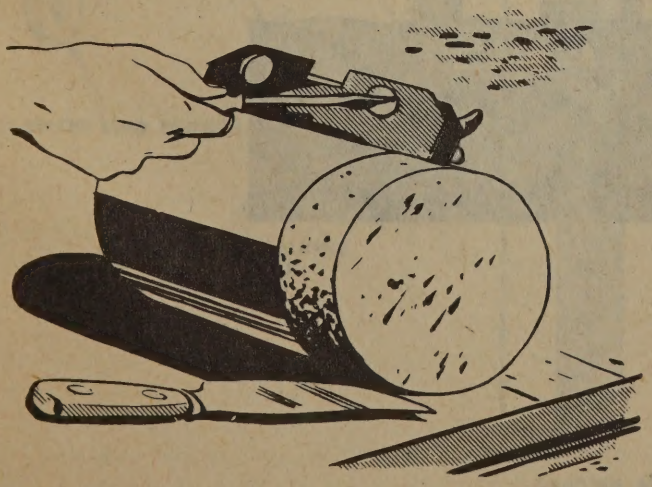
For soils that cannot be sampled with the CBR mold, use a split jacket.



This jacket is not furnished with the set but can easily be improvised as shown above.

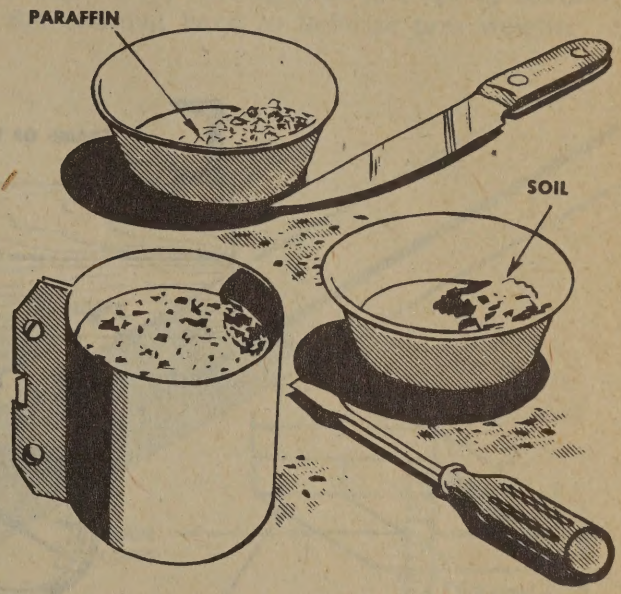


An undisturbed sample is obtained with this jacket in the same manner as for a box sample (page 30). It is prepared for testing as follows:



1. Loosen bolts, expand jacket, and loosen sample from sides.
2. Push sample so it extends about 1 inch out from end of jacket, then reclamp.
3. Remove exposed paraffin with knife, carefully trim sample down to rim of jacket, and check with straightedge.

NOTE: All paraffin and trimmed soil must be saved to compute dry unit weight of material by method shown on page 64 .



4. Loosen bolts, lower sample back to original position, then tighten bolts. The sample is now ready for soaking and testing.

Soaking the Samples

The procedure for soaking undisturbed samples is the same as for laboratory-compacted samples (page 74).

Test Procedure

The penetration test for undisturbed samples is the same as for laboratory-compacted samples (pages 74 to 77). If samples are taken in the CBR mold it is necessary to attach the extension collar since the end of the sample may extend beyond the rim of the mold after soaking. The extensometer stem is adjusted to bear on rim of extension collar.

TEST ON SOILS IN PLACE

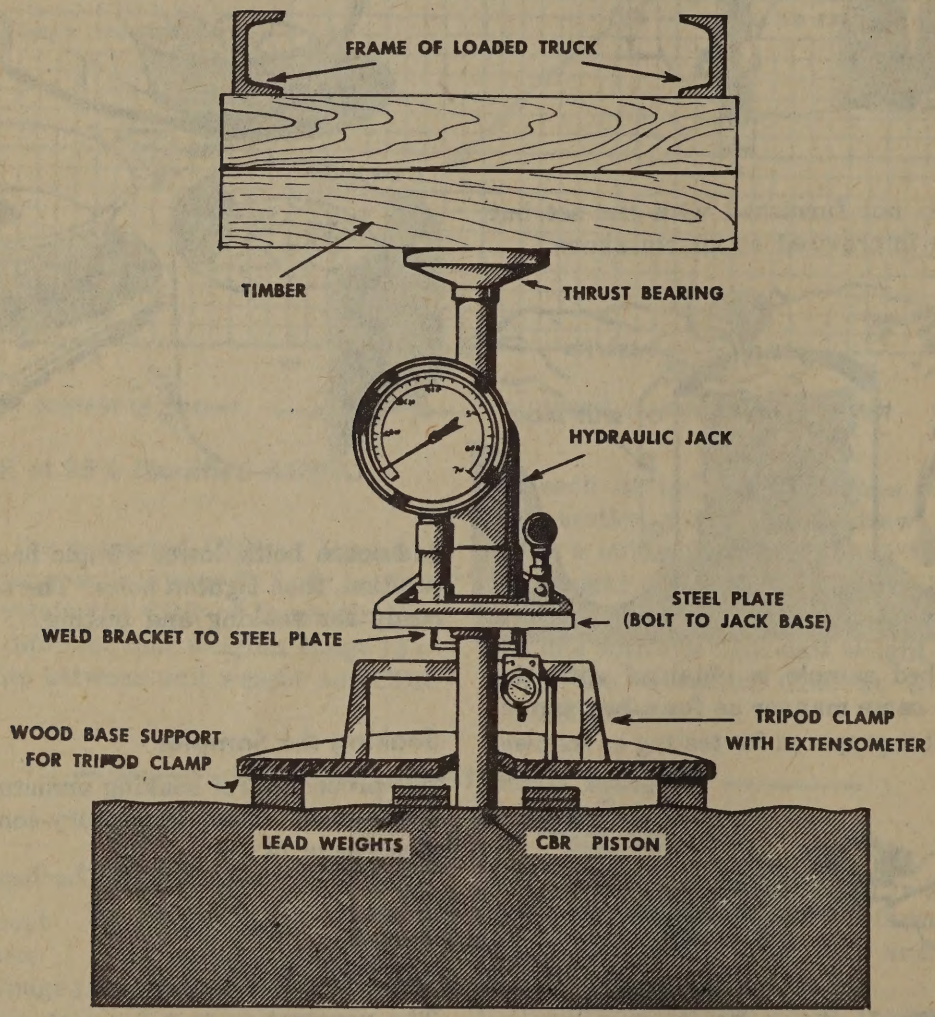
Modified equipment for testing soils in place is not available but can be easily improvised.

Apparatus Required

Hydraulic jack	Stop watch
Piston	Lead weights
Thrust bearing	Improvised equipment
Dial extensometer	

Test Procedure

1. Choose a site with no exposed stones larger than ¾ inch, and carefully smooth and level a 12-inch circle on ground.
2. Place required surcharge weights (step 1, page 74) in center of circle and place test apparatus in position as shown. The weight of apparatus will seat piston firmly.
3. Proceed with steps 4 and 7, page 75
4. Determine unit weight and moisture content of soil in place.



UNCONFINED COMPRESSION TEST

General

Strength of unweathered clayey soils can be determined by the unconfined compression test, a simple substitute for more cumbersome field tests.

Although the set does not include special equipment for this test, it can be readily improvised in the field.

The same sample should be used for both unconfined compression tests and general classification tests.

Apparatus Required

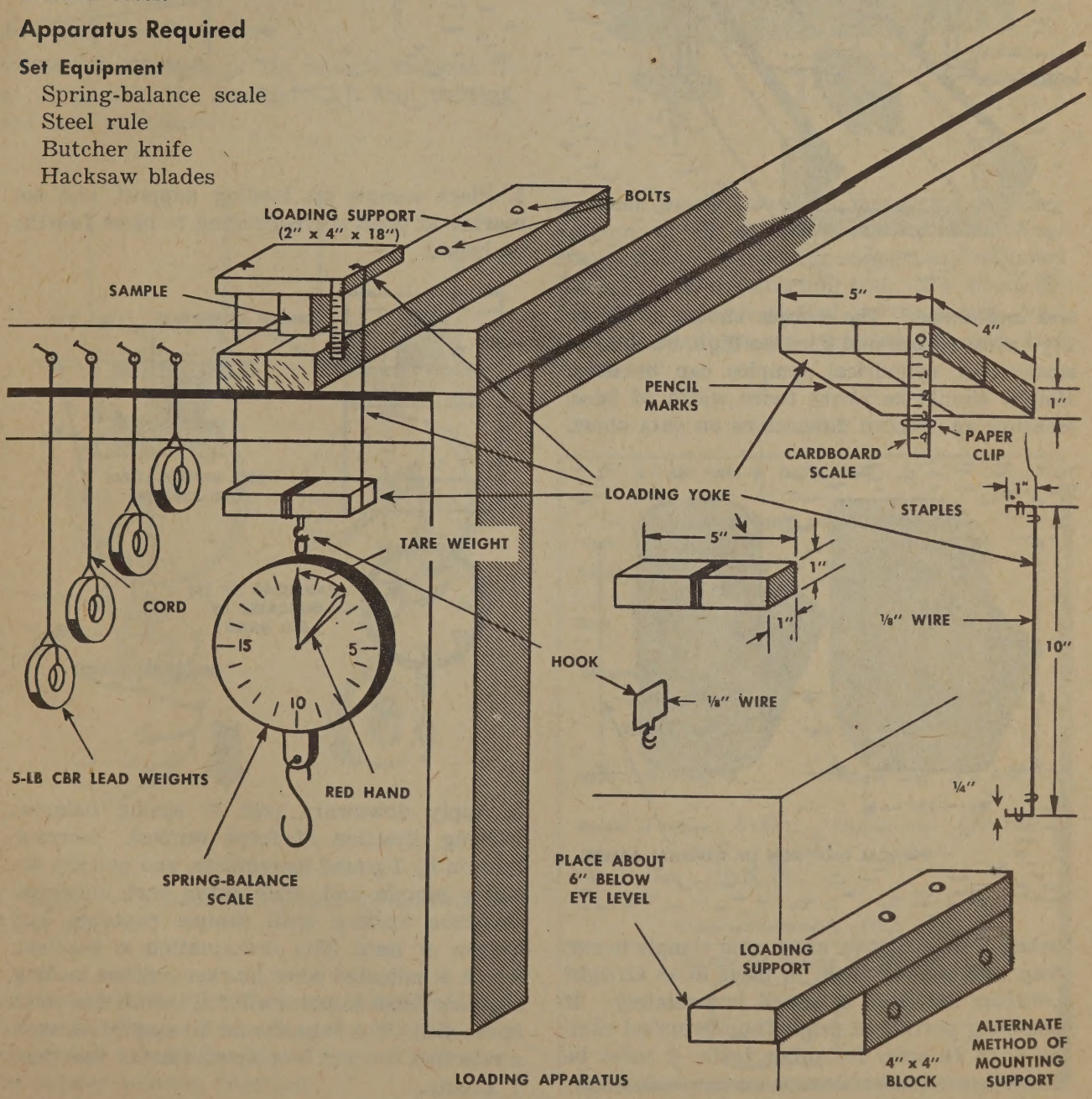
Set Equipment

Spring-balance scale
Steel rule
Butcher knife
Hacksaw blades

Supplemental Equipment

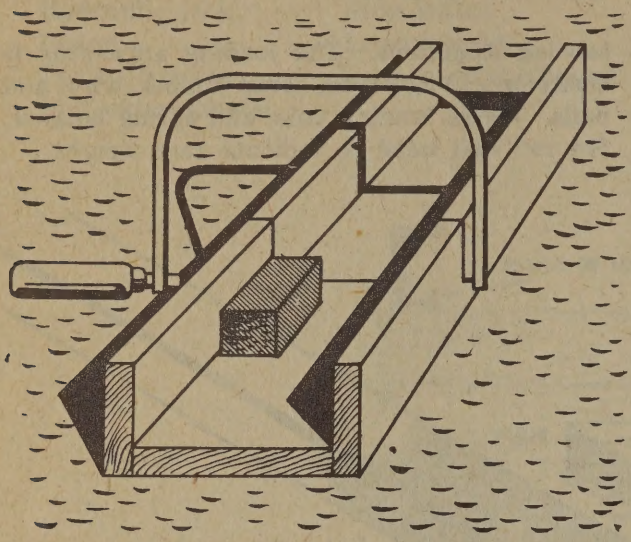
Wire saw (page 18)
Miter box (page 18)

Loading Apparatus. The loading apparatus is easily improvised from scrap lumber, wire, and nails. Weigh loading yoke and spring balance. Set red dial hand to indicate tare weight.

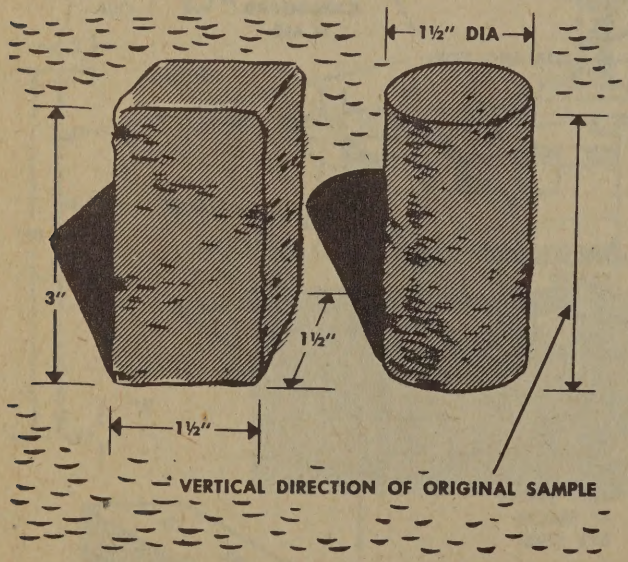


Preparing Sample

Trimming. Trim one or more small samples from the original undisturbed sample with a wire saw. Long dimension of trimmed sample should conform to vertical direction of original sample.

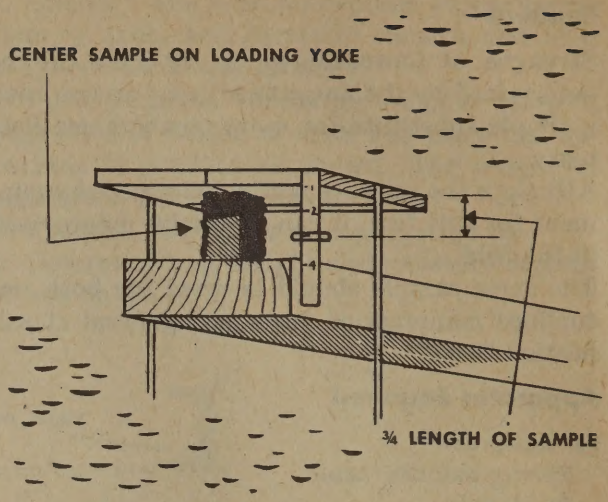


Size and Shape. The sample should be about 1½ inches square and 3 inches high, but larger, smaller, or cylindrical samples can be used. Height should be about twice width of base. Measure and record dimensions on data sheet.

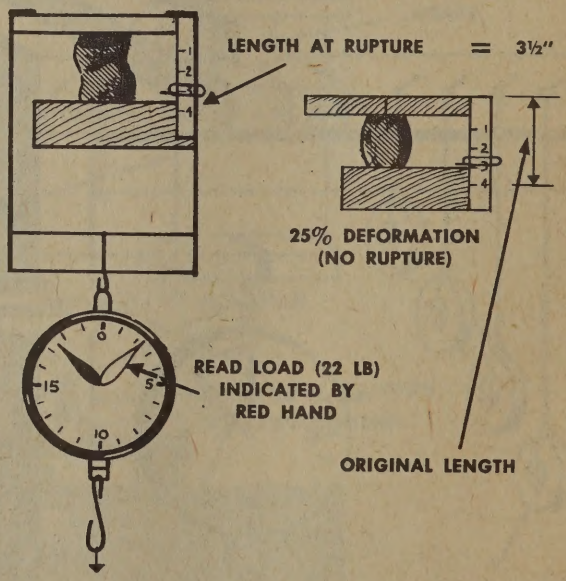


Sealing. Immediately after each sample is cut, wrap with sealing paper or place in an airtight container unless it is tested immediately. If remaining portion of original undisturbed sample is to be used for other tests, it must be resealed.

Test Procedure



1. Place sample on loading support and set marker at point corresponding to three-fourths of height.



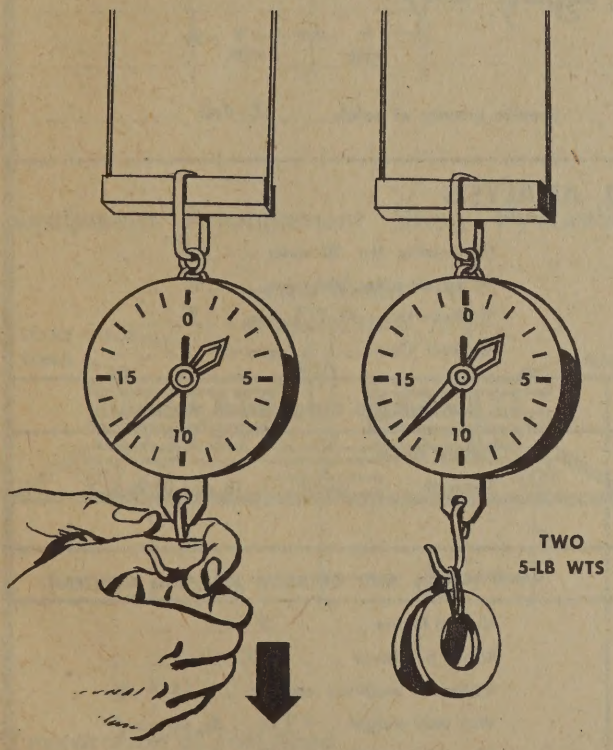
2. Apply downward pull to spring balance, keeping direction of force vertical. Increase tension by 1-pound increments, and quickly observe sample and scale after each increase. Continue loading until sample ruptures and breaks or until 25% deformation is reached, which is indicated when marker reaches loading support. Most samples will fail before this point is reached. The load should be applied at such a rate that the test is completed in not less than 1 minute.

3. Record total load (indicated by red hand on dial) and length of sample (indicated by scale) at rupture or 25% deformation.

If two men perform the test, one man applies the load and calls out dial readings while the other man observes the sample and deformation and records the data. More accurate observation of the load and condition of the sample at failure is possible with this method.

Alternate Test Procedure

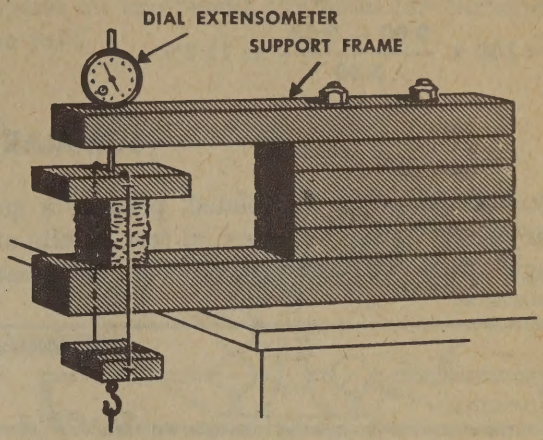
When the strength of the sample exceeds 15 to 20 pounds, the 5-pound CBR lead weights are used as follows:



1. Apply 10 pounds in 1-pound increments by hand pull.

2. Replace this load with a pair of 5-pound lead weights (10 pounds on a looped cord). At the same time release hand pull so load indicated by pointer remains constant.

3. Apply 10 additional 1-pound increments by hand pull, then replace with 2 more 5-pound lead weights as in step 2. Repeat this procedure until sample fails.



To obtain greater accuracy in measuring deformation, one of the dial extensometers with the set is mounted on the loading support and adjusted for height before starting test. If a stress-deformation curve is plotted for the sample, load and dial readings are recorded for each load increment.

DATA SHEET

UNCONFINED COMPRESSION TEST

Sample No SF-P7-2

Date 19 JUNE 1945

Dimensions:

Width 1.40" Height 3.00"

Breadth 1.30" Diameter —

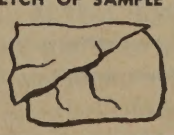
Area 1.82 Sq in Failure load 2218

Height at failure 2.66 Elapsed time 1½ MIN

Failure strain 11.3%

Compressive strength 107 PSI

SKETCH OF SAMPLE AT FAILURE



Sample Calculation

Percent strain at failure

$$= 100 \times \frac{\text{original ht} - \text{final ht}}{\text{original ht}}$$

$$= 100 \times \frac{3.00 - 2.66}{3.00} = 11.3\%$$

Compressive strength

$$= \frac{\text{failure load} \times (100 - \text{failure strain})}{100 \times \text{area of sample}}$$

$$= \frac{22 \times (100 - 11.3)}{100 \times 1.82}$$

$$= 107 \text{ psi}$$

SUMMARY OF TEST DATA

After all tests are completed, prepare a summary sheet listing all essential test results on a single form. For large projects, additional summary sheets may be desired for special records such as listing all unit-weight tests.

SUMMARY OF TEST DATA

Sample No SF-P3-2

Description of material: well-graded sandy gravel, slightly silty

Natural moisture content 3.7 %

Specific gravity of solids 2.66

MECHANICAL ANALYSIS

Maximum size 1"

60% size 4.0 mm

10% size 0.17 mm

Uniformity coefficient 23.5

% passing No. 40 sieve 18

% passing No. 200 sieve 6

% finer than 0.02 mm 3

% finer than ____ mm

PLASTICITY

Liquid limit 20

Plastic limit 17

Plasticity index 3

UNCONFINED COMPRESSIVE STRENGTH

Failure strain ____ %

Strength ____ lb per sq inch

UNIT WEIGHT

Wet unit weight ____ lb per cu ft

Moisture content ____ %

Dry unit weight ____ lb per cu ft

COMPACTION AND OPTIMUM MOISTURE CONTENT

No. of layers 5

Blows per layer 25

Optimum moisture content 11.5 %

Wet unit weight 136 lb per cu ft

Dry unit weight 122 lb per cu ft

CALIFORNIA BEARING RATIO

No of layers 5

Blows per layer 55

Unsoaked sample:

CBR at 0.1" penetration ____ %

Average moisture content ____ %

Dry unit weight ____ lb per cu ft

Wet unit weight ____ lb per cu ft

Soaked sample:

CBR at 0.1" penetration 36 %

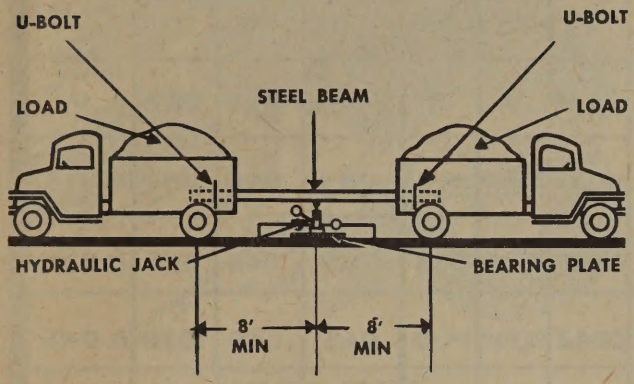
Moisture content (top inch) 17.8 %

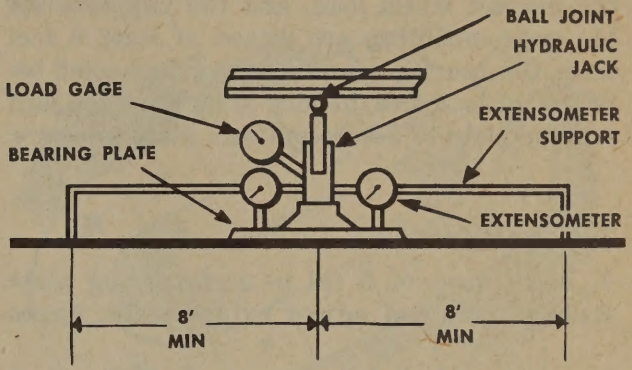
Swell 1.2 %

Dry unit weight 123.1 lb per cu ft

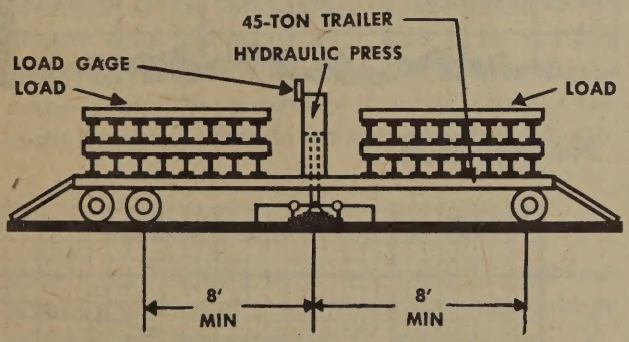
Plate bearing tests require special equipment not included with the soil testing set. Two suggested arrangements are shown below. Details depend on equipment available for performing the test.

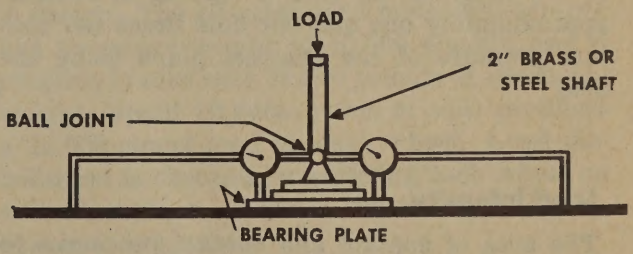
Equipment Arrangement Using Hydraulic Jack





Equipment Arrangement Using Hydraulic Press





Preparation of Test Area

The plate bearing test is made on the base course or surface in its existing state. Artificial saturation by ponding is generally unsatisfactory and gives unreliable results.

Bearing Plate

The load is applied to a rigid circular bearing plate having an area approximately equal to the tire imprint for the expected load. A 30-inch-diameter plate is commonly used for airfield work, but 20-, 12-, and 8-inch plates are sometimes used when heavy test apparatus is not available. A thin layer (not exceeding ¼ inch thick) of fine dry sand may be used to level the soil surface.

Hydraulic Jack

The hydraulic jack or press used to apply the load must have a pressure gage and should have a capacity of 40 tons or more if a 30-inch plate is used.

Layout

The bearing plate is located at least 8 feet from the nearest wheel load, and the supports for the gage mounting are placed at least 8 feet from the bearing plate. Place a ball joint between the load and the jack or between the jack and the plate to assure uniform plate pressure.

Test Procedure

1. Apply load of 5 psi to seat bearing plate. Release load and adjust extensometer gages.

2. Apply loads in 5-psi increments. After each increment of load is applied, allow most of settlement to take place before recording gage readings.

3. Continue the loading beyond the yield point of the material, or until a loading is reached approximately one and one-half times the contact pressure of the heaviest plane using the field.

Load Intensity

The area of contact and contact pressures for military aircraft are listed below.

WHEEL LOAD (LB)	CONTACT PRESSURE (PSI)	CONTACT AREA (SQ IN)
60,000	75	800
37,000	65	570
15,000	55	273
5,000	45	111

Data Sheet

DATA SHEET

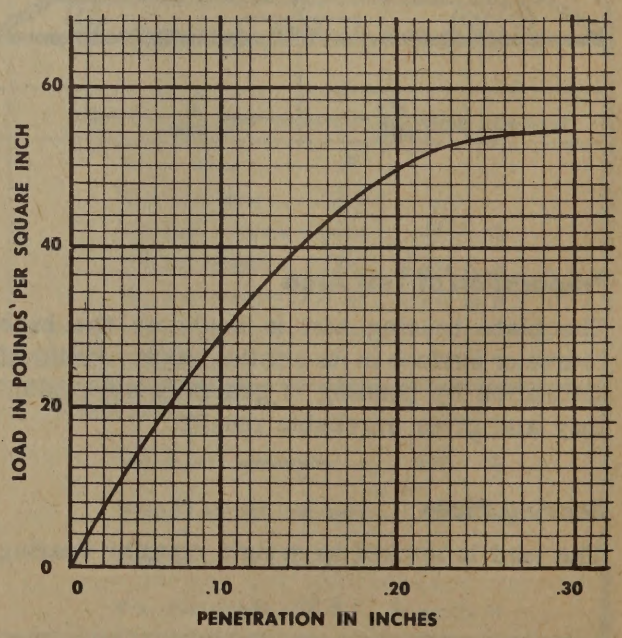
PLATE BEARING TEST

Diameter of plate 30" Date 19 JUNE 45

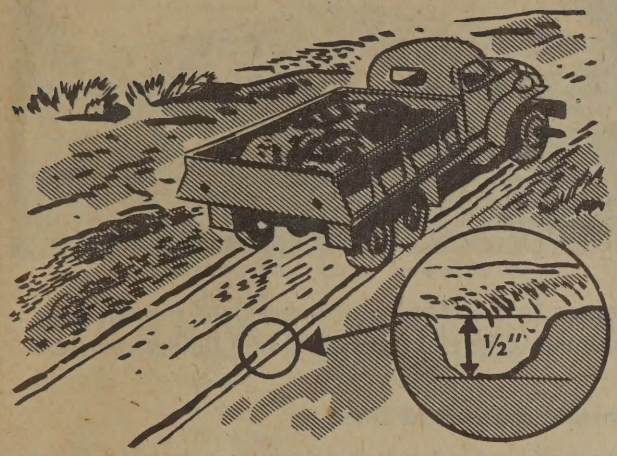
Area of plate 707 SQ IN Test No 1

Time	Load		Gage reading (in)			Penetration (in)
	(lb)	(psi)	Left	Right	Ave	
0630	0	0	.020	.030	.025	0
0835	3,500	5.0	.034	.046	.040	0.015
0838	7,000	9.9	.045	.065	.055	0.030
0842	10,500	14.9	.065	.075	.070	0.045
0848	14,000	19.8	.080	.090	.085	0.060
0855	17,500	24.8	.098	.104	0.101	0.076
0859	21,000	29.7	.118	.118	.118	0.093

Plotting Results



Traffic tests are made to determine allowable plane loads for existing runways.

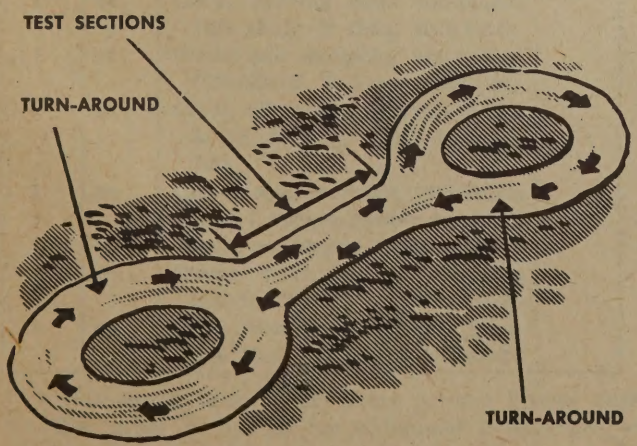


HASTY TESTS

A hasty practical test for stability and wheel supporting capacity of soil may be made by running a loaded truck back and forth several times in the same tracks. If the resulting depression at the midlength of the track is no deeper than about ½ inch, and if no further deepening results with additional running in the same tracks, the subgrade is satisfactory if the same type soil extends for an appreciable depth.

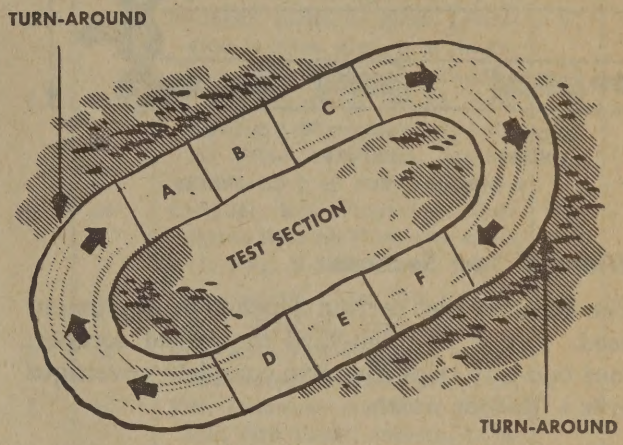
ACCELERATED TRAFFIC TESTS

Accelerated traffic tests are used to simulate actual traffic conditions which the subgrade or surface will be expected to withstand.



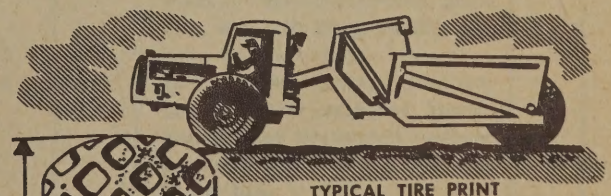
Track Layout

A single-track layout with turn-arounds at each end may be used when only one test section is desired. A double-track layout connected with semi circular turn-around ends is used when several are to be tested.



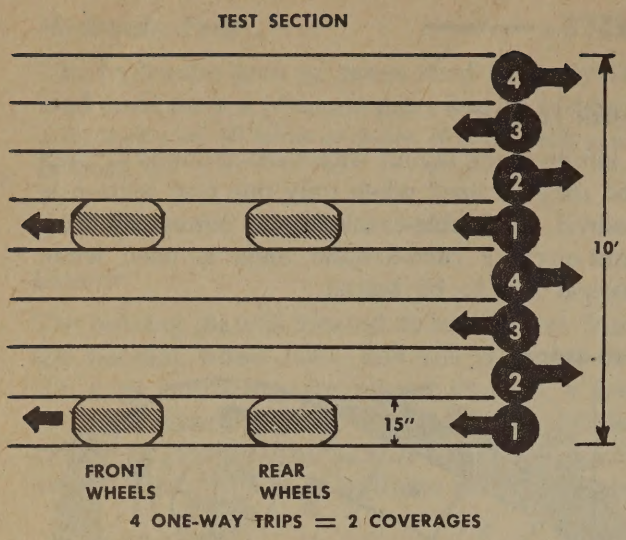
Wheel Loads

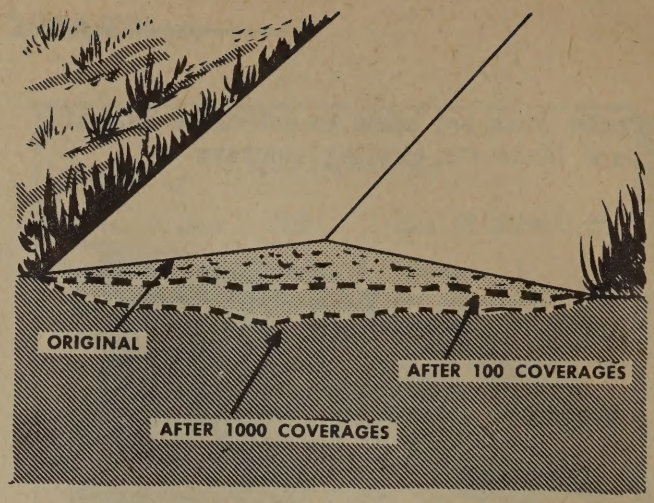
Loaded trucks or motorized scrapers are used to apply wheel loads equal to those to be used in design. The 12-cubic-yard motorized scraper has an empty weight of 30,500 pounds, and if properly loaded with 29,500 pounds of additional weight (about 10 cubic yards of soil) produces a 15,000-pound load on each wheel. Load distribution is checked by weighing each wheel on a level surface. Heavier wheel loads require heavier equipment.



TYPICAL TIRE PRINT
FOR 15,000-LB WHEEL LOAD
12-CU-YD MOTORIZED SCRAPER

TIRE SIZE	18.00 x 24
AIR PRESSURE	47 PSI
GROSS CONTACT AREA	267 SQ IN
CONTACT PRESSURE	56 PSI





Width of Test Sections

The width of test section depends on equipment used. For a 12-cubic-yard motorized scraper, four one-way trips give two complete coverages over a 10-foot width.

Test Procedure

Equipment is operated over the test sections until the required number of coverages is made or until failure occurs. One year's average operation for advanced landing fields and field airdromes in the theater of operations is generally assumed to be the equivalent of 1,000 coverages.

Observations and Data

A test record is kept of subgrade behavior, local failures, roughness, and the like. Cross sections are taken after a specified number of coverages and compared with original cross sections to determine settlement and subgrade displacement. Various tests such as unit weight, CBR, and moisture content are made before and after the test is completed. Photographs are an important part of traffic test records.

APPENDIX

CATALOG LISTING OF LABORATORY SOIL TESTING SET NO. 1[1]

Quantity	Unit of measure	Nomenclature[2]	Expendable
2	ea	Auger, posthole, Iwan type, 6-in.	
20	ea	Bag, drill, unbleached (FS CCC-D-651, type A), material testing, with draw string, 10x18 in.	
5	ea	Bag, drill, unbleached (FS CCC-D-651, type A), material testing, with draw string, 17x32 in.	
1	ea	Balance, torsion, 4½-kg., with removable pans, sensitive to .25 gram.	
1	ea	Balance, triple beam, with extra weight, .01 gram to 201 grams.	
1	ea	Bearing, thrust, special, California bearing test (E Dwg. M-4311-1).	
12	ea	Blade, hacksaw, hand (ES T-1656, type B), flexible, 10-in., 18 teeth.	x
2	ea	Book, note, level.	x
12	ea	Box, tin, seamless, round, low form, flat bottom, Fisher No. 3-490 or equal, 4-oz. capacity.	x
12	ea	Box, tin, seamless, round, low form, flat bottom, Fisher No. 3-490 or equal, 8-oz. capacity.	x
1	ea	Bracket, dial gage, California Bearing Test (E Dwg. M-4311-1).	
2	ea	Brush, paint, metal bound, flat, medium grade, 1-in. wide (ES T-527).	
2	ea	Brush, paint, metal bound, flat, medium grade, 2 in. wide.	
5	ea	Bucket, general purpose, iron galvanized (FS RR-B-771), heavy weight (type II), 14-qt.	
1	ea	Bumper, gage bracket, California Bearing Test (E Dwg. M-4311-1).	
1	ea	Chest, bearing ratio equipment (ES 23-1B, E Dwg. 3832-1-2-3).	
1	ea	Chest, soil sampling equipment (ES 23-1B, E Dwg. 3830-1-2).	
1	ea	Chest, soil testing equipment (ES 23-1B, E Dwg. 3831-1-2-3-4-5-6-7-8).	
1	ea	Chisel, woodworkers' (FS GGG-C-311), socket, firmer (type A), handled, single, ¾-in.	
1	ea	Clamp, gage tripod, California Bearing Test (E Dwg. M-4311-2).	
2	ea	Collar, sampling, California Bearing Test (E Dwg. M-4311-2).	
1	ea	Cover, sieve, testing, 8-in. diameter (FS SS-R-406) (interchangeable with standard sieve).	
2	ea	Cylinder, lucite or glass, graduated in 10-cc. divs., 0 to 100 cc., 5-in. height, 120-cc. capacity.	x
1	ea	Cylinder, material testing, compacting, 1/30 cu. ft. volume, collar fitted with lugs, Aminco 7-252.	
6	ea	Cylinder, soil compaction, California Bearing Test, with collar (E Dwg. M-3411-2).	
1	ea	Duck, cotton, 16-oz. (FS CCC-D-771), 60x60-in., hemmed.	x
1	ea	File, American standard, single, half round, second cut, 12-in.	
1	ea	File, American standard, single, mill (QS 17-79), smooth, 12-in.	
1	ea	Filler, battery, rubber-bulb type, 6-oz., 10¾ in. long.	x
1	ea	Frame, loading, California Bearing Test (E Dwg. M-4311-1).	
1	ea	Frame, testing sieve, Tyler rocker type, with removable rockers and rocker pan.	
6	ea	Handle, auger, posthole, 4- to 8-ft. extension, Iwan No. 8 or equal.	x
1	qt	Hydraulic jack fluid, for Blackhawk jack, 1-qt. can.	x
3	ea	Indicator, dial, adjustable type, with telltale hand, range 1-in., B. C. Ames type 282 or equal.	
1	ea	Jack, hydraulic, California Bearing Test, 8-ton capacity, w/-6,000-lb. zero-correction gage, 6-in. dial (E Dwg. M-4311-1).	
2	ea	Knife, butcher, 6-in.	
5	bx	Label, paper, blank, gummed, oblong, white with red border and clipper corners, Dennison or equal, 4 11/16x2 in., No. 2003, 30 to box.	x
1	ea	Liquid limit machine, soil testing equipment, complete with brass cup and Casagrande-type grooving tool, American Instrument Co. 7-177 or equal.	
3	ea	Mold, highway material testing, cylinder, 2-in. diameter x 4 in. high.	

[1] This listing taken from Army Service Forces Catalog ENG 6 560-01, 11 December 1944.

[2] See pages 7 to 13 for equipment illustrations and nomenclature as used in this Technical Bulletin.

Quantity	Unit of Measure	Nomenclature	Expendable
1	ea	Opener, can, mechanical, wall type.	
1	ea	Oven, material testing, steel insulated, mica window.	
12	ea	Pad, memorandum (FS UU-P-21), for ink writing (type II), white, plain, 5x8 in.	x
24	ea	Pan, pudding, enamel, 9-in. diam. at bottom, 4 in. high.	
1	ea	Pan, sieve, testing, 8-in. diameter (FS SS-R-406), interchangeable with standard sieve.	
100	sh	Paper, cross section printed (FS UU-P-201, class B), tracing (type II), tenth line heavy, engraved orange, in sheets, 8½x 11-in. width, 10x10 sections to inch.	x
1	bx	Paper, filter, quantitative, Whatman or equal, No. 41H, 15-cm, 100 circles to box.	x
50	sh	Paper, logarithmic (FS UU-P-201), printed, tracing (type II), semilog, engraved green, in sheets, 8½- x 11-in. size, 3 cycles x 10-to- in. type of engraving.	x
25	lb	Paraffin (wax) (FS VV-P-121), grade B, 1-lb. cake.	x
6	ea	Pencil, paper cased (spiral wound), wax, china marking, black.	x
12	ea	Pencil, wood cased, lead, general writing (FS SS-P-166, type IV), with eraser, No. 3.	x
1	ea	Piston, steel, California Bearing Test, (E Dwg. M-4311-2).	
3	ea.	Plate, base, perforated, California Bearing Test, with adjustable bronze stem (E Dwg. M-4311-2).	
1	pr	Pliers, side cutting, 6-in.	
1	ea	Rule, steel, spring tempered (FS GGG-R-791), English (type D), 12-in., 16ths, 32ds, 64ths graduation.	
2	ea	Rule, tape, steel pull-push, 3-flat-side case, inside, outside depth, and height measuring, English, 72-in., 16ths and 32nds graduation.	
1	ea	Scale, weighing (FS AAA-S-121), spring balance, straight single hook, 40-lb. capacity, 1/10th graduation.	
1	ea	Scale, weighing (FS AAA-S-121) spring balance, straight single hook, 60-lb. capacity, 1/10th graduation.	
1	ea	Screen, testing sieve, Tyler rocker type, ¼-in. opening.	
1	ea	Screen, testing sieve, Tyler rocker type, ¾-in. opening.	
1	ea	Screen, testing sieve, Tyler rocker type, 1½-in. opening.	
1	ea	Screen, testing sieve, Tyler rocker type, 2-in. opening.	
1	ea	Screwdriver, common, wood handle, (FS GGG-S-121, type III), normal duty (class C), 8 in. long, ⅜-in. wide blade.	
		Sieve, testing, woven wire cloth (FS SS-R-406), 8-in. standard sieve frame, half-height, coarse series:	
1	ea	¼-in.	
1	ea	¾-in.	
1	ea	1-in.	
		Sieve, testing, woven wire cloth (FS SS-R-406), 8-in. standard sieve frame, half-height, fine series:	
1	ea	No. 4	
1	ea	No. 10	
2	ea	No. 40	
1	ea	No. 60	
2	ea	No. 100	
2	ea	No. 200	
2	ea	Spatula, laboratory, steel blade, wood handle, 4-in. blade, ½-in. wide.	
2	ea	Spoon, cooking, basting, steel, tinned, 14 in. long.	
2	ea	Stove, gasoline burning, portable, 2-burner, 14¾x9½x4½ in. overall, complete w/wind baffle and carrying case, Coleman model No. 523 or equal.	
1	ea	Straightedge, steel (FS GG-S-776), one edge beveled (type II), 12-in.	
100	ea	Tag, shipping (FS UU-T-81), cloth (type A), white 2⅜x4¾ in., No. 5.	x
1	ea	Tamper, soil-compaction cylinder, brass, with guide, Aminco 7-254H, 10-lb.	
1	ea	Thermometer, general laboratory, circular graduated dial, 8-in. steel stem, 1½-in. dial, 50° to 300° F.	x

Quantity	Unit of Measure	Nomenclature	Expendable
12	ea	Towel, crash (FS DDD-T-511), cotton (type B), 17x36 in.	
2	ea	Trowel, pointing (FS GGG-T-671), (type D), 2¼x4¾-in. blade.	
1	ba	Twine, cotton, seine (FS T-T-881), cable laid, No. 30, 4-oz. ball.	x
1	ea	Watch, stop (FS GG-W-111, type A), noncontinuous running (class 7).	
1	st	Weight, balance, inset, nested coarse weighing, 5 to 2000 grams.	

Quantity	Unit of Measure	Nomenclature	Expendable
10	ea	Weight, lead, California Bearing Test, 5-lb., 2 1/16-in. i. d., 5⅞-in, o. d. (E Dwg. M-4311-2).	
1	ea	Wrench, adjustable, crescent type, single end (FS GGG-W-631, type I, class B), 1⅛-in. opening, 10-in. long.	
4	ea	Wrench, pipe, adjustable, Stillson pattern (FS GGG-W-651), heavy duty (type II), ¼- to 1-in. capacity, 10 in. long.	

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